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A study of pressure-volume rates and plenum membrane additions to the captured air bubble surface effect ship XR-3 digital computer loads and motion program

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A STUDY OF PRESSURE-VOLUME RATES AND PLENUM MEMBRANE ADDITIONS TO THE CAPTURED AIR BUBBLE SURFACE EFFECT SHIP XR-3 DIGITAL COMPUTER LOADS AND MOTION PROGRAM

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THESIS

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by

John Martin Boggio

June 1976

Thesis Advisor: A. Gerba, Jr.

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I. INTRODUCTION

A. BACKGROUND

The Captured Air Bubble Surface Effect Ship (CAB SES) offers a dynamic new approach to improve surface ship performance. As with any new approach, extensive testing at the design stage of development is required. The U.S. Navy has been conducting sea trials on two 100 ton Captured Air Bubble (CAB) test craft, the 100-A and the 100-B [Ref. 1]. In addition to scale model testing, another approach to design evaluation involves the use of high speed digital computers to simulate the dynamic performance of the craft.

A digital computer Loads and Motion (L&M) program for the CAB SES was developed under government contract by the Oceanics Corp. [Ref. 2]. The L&M program installed at the Naval Postgraduate School, W. R. Church, computer facility on an IBM 360/67 computer was for a 100 ton displacement test craft, the 100-B. Leo and Boncal [Ref. 3] modified this computer program to represent a smaller 3 ton craft, the XR-3. The XR-3 is an operational test craft currently maintained and operated by the Naval Postgraduate School [Ref. 4].

Various modifications and changes to Leo and Boncal's basic work have been implemented. Finley, Forbes, and Menzel, in Refs. 5-7, provides program changes to obtain better representation of the Fan maps, bow and stern seal dynamics and pitch and roll damping.

One adverse characteristic of both the 100-B computer program and the XR-3 computer program was the extensive use of the digital computer time when operating in simulated sea states. Since the 100-B and the XR-3 programs are similiar, the computer time analysis provided by Mitchell [Ref. 8] for the 100-B also applies to the XR-3 program.

Another aid to design is the testing done in towing tanks in which scale models are used. Towing tests were conducted at NSRDC using a rubber membrane installed on the forward portion of a CAB SES model in order to better scale the pressure-volume relationship [Ref. 9]. The addition of this membrane improved the pitch and heave characteristics of the scale model in sea state operation.

B. OBJECTIVES

It is the objective of this work to examine the L&M digital computer program and make any changes that would improve the program with particular attention to changes that would reduce the amount of time required to execute the program.

A second objective is to model the plenum membrane, add the required program changes and study the effects of the membrane on simulated craft performance.

II. PROGRAMMING CHANGES

A. RATE EQUATIONS FOR PRESSURE AND VOLUME

1. Introduction

An examination of the dynamics of the XR-3 L&M program indicate that the key parameters of this type of ship design are those which describe the dynamic behavior of the bubble of the air in the plenum. This pressure of air provides approximately 75% of the lift force when the craft is "on the bubble." Small changes in bubble volume and pressure therefore cause significant changes in total ship response. These variables were examined in an effort to decrease the digital computer simulation execution time.

2. SUBROUTINES RHS and INTGRL

The force and moment equations for the craft are the six degrees of freedom equations plus four auxillary equations contained in SUBROUTINE RHS [Ref. 2].

The integration of these equations is performed in SUBROUTINE INTGRL. INTGRL uses the Runga-Knutta-Merson numerical integration technique with an automatic variable step size. If the error tolerances specified are exceeded the step size is reduced and the step repeated until all error tolerances are met or the step size is reduced to 1×10^{-6} sec., at which point the program stops. Thus the integration values are forced to converge to their correct values. All ten equations are integrated serially at the

same time step. When all integration error tolerances are met INTGRL returns the integrated values and increases the simulation time one time-step increment. Since pressure and volume are key variables, integrating their rates should cause the system of equations to converge more rapidly to their true values and avoid any problems associated with the feedback loops in the pressure-volume calculation [Ref. 10].

3. Formulation of Volume Rate and Pressure Rate

The bubble pressure equation is for an adiabatic process [Ref. 2].

$$P_b = P_a \left(\frac{\rho_b}{\rho_a} \right)^{\gamma} \tag{1}$$

where the subscripts a and b represent atmosphere and plenum values respectively

P = pressure absolute

ρ = density $\frac{M}{V}$ (2)

γ = adiabatic exponent for air

Substituting (2) into (1)

$$P_b = P_a \left(\frac{M}{V \rho_a} \right)^{\gamma} \tag{3}$$

Differentiating (3) with respect to time where P_a and ρ_a are assumed to be constant yields

$$\dot{P}_b = \frac{P_a}{\rho_a} \gamma \left(\frac{M}{V \rho_a} \right)^{\gamma-1} \left(\frac{V\dot{M} - M\dot{V}}{V^2} \right) \tag{4}$$

Factoring $\frac{M}{V}$ from the last term of (4)

$$\dot{P}_b = \gamma P_a \left(\frac{M}{\rho_a V}\right)^{\gamma-1} \left(\frac{M}{\rho_a V}\right) \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V}\right) \qquad (5)$$

Noting $\left(\frac{M}{\rho_a V}\right)^{\gamma-1} \left(\frac{M}{\rho_a V}\right) = \left(\frac{M}{\rho_a V}\right)^{\gamma}$

and

$$P_a \left(\frac{M}{\rho_a V}\right)^{\gamma} = P_b$$

$$\dot{P}_b = \gamma P_b \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V}\right) \qquad (6)$$

The volume equation for the bubble is computed in RHS in four parts and summed together

$$V = Vnom - D - WA + WT \qquad (7)$$

The four terms that determine volume are

(1) Vnom = the empty plenum volume

(2) D = draft term-change in volume due to draft

(3) WA = Wave term-change in volume due to the presence of waves

(4) WT = WATSLP term-- correction term for the added volume wedge which is a function of speed [Ref. 6].

Differentiating equation (4)

$$\dot{V} = -\dot{D} - \dot{WA} \qquad (8)$$

where

$\dot{WA}$ = rate of change of volume due to waves

$\dot{D}$ = rate of change of volume due to displacement

$\dot{WT}$ = 0.0

$\dot{V}nom$ = 0.0

$\dot{WA}$ is computed in SUBROUTINE WAVES by taking the difference in change of volume due to waves at successive time steps and dividing by the time step. Since WATSLP is a function of speed, the differentiated value of WATSLP, $\dot{WT}$, is a function of acceleration. Forward accelerations are normally small; therefore, the differentiated value of WATSLP was approximated to be zero. Equations (4) and (5) were programmed as follows:

```
VALUE  (11)  = -(((XL*WIDTH)-ABW)*.5*W)-DVWDOT
VALUE  (12)  = GAM*VAL(13)*(VALUE(10)/VAL(11)-VALUE(11)/
               VAL(12))
```

where

DVWDOT = rate of change of volume due to waves

VALUE(10) = Bubble mass flow rate

VALUE(11) = Volume rate

VALUE(12) = Pressure rate

VAL(11) = Bubble Mass

VAL(12) = Bubble Volume

VAL(13) = Bubble Pressure

GAM = Adiabatic Exponent for air

B. ELIMINATION OF SUBROUTINE DMINV

In an effort to improve program timing, the suggestions given in Ref. 7 were undertaken. One recommendation suggested the removal of SUBROUTINE DMINV in the 100B L&M program by making changes to SUBROUTINES INCON and RHS. An examination of the L&M program indicated that these changes also could be applied to the XR-3 program. Consequently the following was deleted:

```
212   DO 211 I = 1,6
      DO 211 N = 1,6
211   A(I,N)   = 0.0
      DO 213 N = 1.3
213   A(N,N)   = AM
      A(4,4)   = AIXX
      A(5,5)   = AIYY
      A(6,6)   = AIZZ
      A(4,6)   = -AIXZ
      A(6,4)   = -AIXZ
      AIMAX    = AMAXI(AM, AIXX,AIYY,AIZZ,ABS(AIXZ))
      DO 214 I = 1,6
      DO 214 J = 1,6
214   A(I,J)   = A(I,J)/AIMAX
      CALL DMINV(A,G,D,)
      DO 215I  = 1,6
215   A(I,J)   = A(I,J)/AIMAX
      IF (D.NE.0.0.) GO TO 10
      WRITE (6,216)
      STOP
```

In place of the above the following was added:

```
215   AMASSI = 1.0/AM
      D      = 1.0/(AIXX*AIZZ-AIXZ*AIXZ)
      DIXX   = AIXX*D
      DIXZ   = AIZZ*D
      DIZZ   = AIZZ*D
      AIYYI  = 1.0/AIYY
      GO TO 10
```

Linkage between INCON and RHS was provided by the following

```
COMMON/ATRIX/AMASSI,AIYYI,DIXX,DIXZ,DIZZ
```

In SUBROUTINE RHS the six element matrix GF(J) was deleted and the following identifiers were substituted for the summation of forces: SUMX, SUMY, SUMZ, SUMK, SUMM, SUMN. In addition, the following deletion was made.

```
DO 1 I = 1,6
VALUE(I) = 0.0
DO 1 J = 1,6
VALUE (I) = VALUE (I) + A(I,J)*GF(J)
1 CONTINUE
```

Substituted for the above DO LOOPS was the following

```
VALUE (1)  = SUMX*AMASSI
VALUE (2)  = SUMY*AMASSI -R*U
VALUE (3)  = SUMZ*AMASSI
VALUE (4)  = SUMK*DIZZ + SUMN*DIXZ
```

VALUE (5) = SUMM*AIYYI

VALUE (6) = SUMN*DIXX + SUMK*DIXZ

These changes eliminated SUBROUTINE DMINV and several DO LOOPS.

C. EXPANSION OF WAVE COMPONENTS

Since the program was being tested with sea state, the method used for the wave generation was studied. SUBROUTINE INCON provides a means of introducing sea-state by individual wave components and amplitudes. In addition, the subroutine will accept an average height and lowest and highest wave frequency and/or wave period and generate up to 10 wave components.

These wave components represent a sampling of the spectural energy density of the given sea state condition. Reference 11 suggests for irregular sea, a minimum of 15 - 20 components are required to simulate irregular sea conditions. The program dimension statements were accordingly increased from 10-20 to determine if any significant changes could be observed by increasing the number of wave components.

D. MISCELLANEOUS

Each subroutine was examined with regard to efficiency of coding and changes were implemented such as multiplication in lieu of the use of the exponential. For example, IBM 360/67 fixed point exponentiation requires that the natural logarithm be generated and then a logarithm be computed, as compared

to straight forward multiplication. When such exponentiation is nested in DO LOOPS, a significant time savings can be realized by the use of multiplication.

III. TEST PRODECURES

A. COMPUTER SYSTEM

The digital computer used throughout this study is an IBM 360/67 model, VERSION I, located at the NPS W. R. Church Computer Facility. The system's hardware configuration provides 2 M bytes of core. This main core is composed of IBM core storage devices (IBM 2365 Mod. 12) and compatable but slightly different Lockheed core storage devices (MM 365). The Lockheed core devices are about 18% slower in execution time than IBM core devices. Since the system is time-shared and the core is contiguous, there is no practical way to determine in which portion of the main core the program is residing. Therefore, exact timing of a program is not easily achieved. In this report all timing values must be interpreted with this anomaly in mind. Among the options available under this operating system are the FORTRAM G and FORTRAN H compilers [Ref. 12]. Mitchell reported substantial time savings using the H compiler [Ref. 8]. Since one of the main objectives was to reduce execution time, computer model testing was done using both compiler options. Runs made under different compilers will be noted.

A word of caution on the use of the H compiler. The H compiler produces its timing improvements and core reduction by coding optimization. This means the compiler re-arranges

the Fortran code. This re-arrangement may move computations outside of DO LOOPS for example. Applicable portions of Ref. 13 should be read and understood before using this feature.

B. TEST CONDITIONS

The L&M program for the XR-3 used in this report is the one given in Ref. 7. This program was then modified to incorporate the changes previously described. The basic program [Ref. 7] computes pressure using eq. (1) and volume using eq. (7) and is referred to as PROGRAM ONE. PROGRAM ONE was used as reference for comparative purposes. The addition of the pressure rate and volume rate equations (6) and (8) and the elimination of SUBROUTINE DMINV constituted major modifications to the basic program. This version of the Loads and Motion program was called PROGRAM TWO. PROGRAM THREE was PROGRAM TWO compiled and executed with the FORTRAN H compiler.

Five test conditions for a given speed were established to provide a full range of disturbances for testing the L&M programs. These test conditions are tabulated in Table I.

In Condition One small disturbances were introduced by changing the initial conditions of draft (DS) and pitch (θ). These changes consisted of decreasing the draft and pitch from previously computed steady state values by the magnitude shown in Table I. In addition, the rudder was held at zero and the sea was calm. In Condition Two, the perturbations were the same as Condition One except that now the rudder

TABLE I

TEST PERTURBATIONS

	Δ DS	Δ θ	RUDDER	SEA STATE
Condition One	0.1 inch	.03	0.0	Calm water
Condition Two	0.1	.03	20^{o}	Calm water
Condition Three	0.0	0.0	0.0	Regular One
Condition Four	0.0	0.0	0.0	Regular Two
Condition Five	0.0	0.0	0.0	Irregular One

was displaced to the right 20 degrees. The rudder was offset at the start of the simulation and held through the run as this value. In Condition Three, Four and Five the only disturbances used were the sea state conditions.

Sea state is generated in SUBROUTINE WAVES. SUBROUTINE INCON generates wave components and amplitudes based on several different type input parameters. [See users manual Ref. 7]. Regular sea one and two are simple sinusoidal waves. Irregular sea state conditions are simulated by the addition of several regular sinusoidal wave components. Sea state used throughout this study is true sea state and is not scaled in any manner.

The L&M program provides two options for propulsion, either constant speed or constant thrust. The constant

thrust option was selected because this is the normal operating mode for the XR-3 test craft.

Integrator tolerance levels were maintained at the values given in Ref. 7. However two new error tolerances had to be determined for the integration of the pressure and volume rates. These new levels were determined by first selecting a very tight value .000001 which was increased in increments until a change in output could be noticed. The value was then decreased by a factor of 10. Pressure and volume tolerance levels were then set at this value which was found to be .0001.

All other variables such as draft and pressure were initialized from the steady state undisturbed conditions for that specific starting speed. The steady state conditions were evaluated by first using the constant speed propulsion option and the initial values in Ref. 7. The program was then run until the key input variables - pitch, draft, thrust and pressure - reached steady state. These values were then read in and propulsion was switched to constant thrust. The program was run again to insure that steady state conditions existed. These steady state values are shown in Table II.

TABLE II

STEADY STATE CONDITIONS

Speed(Knots)	10	20	30
Pressure	23.93	24.84	24.84
Draft	8.17	6.12	5.34
Thrust (each engine)	200.31	218.17	287.22
Pitch	1.62	.48	.26

Pressure in psfg

Draft in inches

Thrust in ft. lb.

Pitch in degrees

IV. MEMBRANE ADDITION

A. INTRODUCTION

During towing tank tests conducted at NSRDC, a rubber membrane was installed on the forward bow of the XR-1 scale model [Ref. 9]. The installation of this membrane improved the pitch and heave characteristics of the scale model during simulated sea conditions. Reference 9 provided the following emperical expression which relates the Pressure and Volume of the membrane.

$$V = KP_b \tag{9}$$

K was experimentally determined and has the value .317 when scaled to the XR-3 test craft dimensions. (See Appendix A).

B. MATHEMATICAL MODELING

The approach used to include the effects of this membrane was to develop mathematical expressions which could be added to the already existing pressure, volume and air mass equations in the L&M program. Five mathematical expressions were developed, tested and referred to as Models One, Two, Three, Four and Five. They are explained below and the results discussed in Section V.

1. Model One

Model One is based on the premise that by correcting the plenum volume with the membrane volume, the equations

in SUBROUTINE RHS would show the effect of the membrane. Model One added the following equation to PROGRAM ONE;

$$V_m = K\ P_m \tag{10}$$

Then using (10) to correct the volume of the plenum and assuming $P_m = P_b$.

$$V = V_b + V_m \tag{11}$$

where V_b is given by eq. (7).

2. Model Two

Model Two is an extension of Model One. Based on the premise that by correcting the rate of change of plenum volume with the rate of change of membrane volume, the rate equations given in SUBROUTINE RHS and subsequent integration of these terms would show the effect of the membrane. Model Two added the following rate equation to PROGRAM TWO.

$$\dot{V}_m = K\ \dot{P}_m \tag{12}$$

Then using (12) to correct the rate of change of plenum volume and assuming

$$\dot{P}_m = \dot{P}_b$$

$$\dot{V} = \dot{V}_b + \dot{V}_m$$

where $\dot{V}_b$ is given by eq. (8).

3. Model Three

Model Three was based on the premise that the volume rate eq. (8) and the pressure rate eq. (6) as computed without the membrane could be corrected for the membrane by adjusting these terms by appropriate factors within PROGRAM TWO.

Correction terms were sought that would be a function of the membrane. A logical candidate for this correction factor for the pressure was the ratio of rates of change of the membrane volume to plenum volume multiplied by plenum pressure rate.

$$PCT = \frac{\dot{V}_m}{\dot{V}_b} \dot{P}_b \tag{13}$$

where PCT is the correction factor to be added to the plenum pressure rate term $\dot{P}_b$ before integration. It was assumed that the pressure and pressure rate of the plenum and membrane were equal.

$$P_m = P_b \tag{14}$$

$$\dot{P}_m = \dot{P}_b \tag{15}$$

It was also assumed that the membrane volume rate and pressure rate were related by

$$\dot{V}_m = K\dot{P}_m \tag{16}$$

Substituting (16) into (13) and using (15)

$$PCT = K \frac{\dot{P}_b^2}{\dot{V}_b} \tag{17}$$

The volume rate correction term was assumed to be the ratio of the rate of change of membrane pressure to the rate of change of plenum pressure times the rate of change of membrane volume.

$$VCT = \frac{\dot{P}_m}{\dot{P}_b} \quad \dot{V}_m \tag{18}$$

where VCT is the correction factor to be added to the plenum volume rate term $\dot{V}_b$ before integration

Since $\dot{P}_m = \dot{P}_b$ and $\dot{V}_m = K\dot{P}_b$

Then from (18)

$$VCT = K\ \dot{P}_b \tag{19}$$

Then using equations (17) and (19) the rate equations are

$$\dot{V} = \dot{V}_b + VCT \tag{20}$$

$$\dot{P} = \dot{P}_b + PCT \tag{21}$$

where $\dot{V}_b$ is given by eq. (8) and $\dot{P}_b$ by eq. (6).

Consider the following. Since K is a function of the elasticity of the membrane, if K = 0.0. Equations (20) and (21) reduce to the no membrane case.

If the membrane expands at the same rate that the volume of the plenum contracts the system volume rates is zero and the system pressure rate is also zero.

4. Model Four

Again using PROGRAM TWO, Model Four was based on the premise that the mass of the membrane air and mass flow rate of membrane air would be important factors in any correction term to be applied to plenum volume rate and pressure rate.

Again it was assumed that the membrane effect could be described as an adiabatic reversible process. Then using Equation (6) applied to the membrane,

$$\dot{P}_m = P_m \gamma \left(\frac{\dot{M}_m}{M_m} - \frac{\dot{V}_m}{V_m} \right) \tag{22}$$

where m denotes membrane

$\dot{M}_m$ = Mass flow rate of the membrane air

M_m = Mass of the membrane air

Again it was assumed that the pressure and pressure rate of the membrane and plenum were equal.

$$P_m = P_b \tag{23}$$

$$\dot{P}_m = \dot{P}_b \tag{24}$$

It was also assumed that the membrane volume rate and pressure rate were related by

$$\dot{V}_m = K \dot{P}_m \tag{25}$$

Equation (25) was obtained by differentiating

$$V_m = K P_m \tag{26}$$

Substituting (25) and (26) into (22) yields

$$\frac{\dot{M}_m}{M_m} = \left(\frac{1+\gamma}{\gamma} \right) \frac{\dot{P}_m}{P_m} \tag{27}$$

One term is not available, M_m. Two possibilities were considered to determine this value. The first possibility would be to integrate $\dot{M}_m$ and use the result of the integration from the preceding time step. The other possibility would be to hold temperatures constant in the membrane, and use the ideal gas law to determine M_m for varying pressure and volume. This last condition would be in error; however, as a first approximation, it would produce acceptable results.

Because of the past history of difficulty with integrator 10, plenum air mass rate, the second possibility was chosen. Evaluation of the terms in the ideal gas law for a temperature of 68^{o} degrees excluding mass, pressure and volume produced the constant.

$$4.9 \times 10^{-7} \quad \text{slugs/psf - ft}^3$$

therefore;

$$M_m = (4.9 \times 10^{-7})\ (P_m)(V_m) \tag{28}$$

Equations (22), (25) and (27) describe the membrane. These equations are used to correct the mass rate and volume rate of the plenum without the membrane.

$$\dot{M}_s = \dot{M} + \dot{M}_m \tag{29}$$

$$\dot{V}_s = \dot{V} + \dot{V}_m \tag{30}$$

where

s = denotes the system of plenum plus membrane

$\dot{M}$ = mass flow rate of plenum

$\dot{V}$ = volume rate of change of plenum

Using (29) and (30) in equation (6) the corrected plenum pressure rate is

$$\dot{P}_s = P_b \gamma \left(\frac{\dot{M}_s}{M} - \frac{\dot{V}_s}{V} \right)$$

where P_b, M and V are values obtained from the previous time-step calculation.

5. Model Five

Model Five is the application of equation (10) to PROGRAM TWO. It is based on the premise that the volume of the membrane could be introduced into the plenum pressure rate equation, and represent the membrane effect.

$$V_m = K P_m \tag{31}$$

$$V = V_b + V_m \tag{32}$$

Equation (31) and (32) are computed as in Model One. Then equation (32) is used in the pressure rate equation.

$$\dot{P} = P_b \gamma \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V} \right) \tag{33}$$

V. DISCUSSION OF RESULTS

A. PRESSURE RATE AND VOLUME RATE CHANGE

The addition of the pressure rate and volume rate equations was implemented without any major difficulty. In order to provide a basis of comparison for computer time analysis a quality factor "Q" was established. "Q" is defined to be the ratio of CPU execution time to problem time. For example, if the problem specified 1 minute of simulation and the CPU execution time (GO STEP in IBM COMPUTER SYSTEMS) was 5 minutes Q = 5.0. PROGRAMS ONE, TWO and THREE were tested with identical input parameters. The results are summarized in Table III and Table IV.

Runs were compared using PROGRAM ONE as a reference. No differences in computed output were noted for Condition One thru Four and only small changes in computed values noted with Condition Five. The integrator error tolerance levels were maintained constant for all runs.

As can be seen from the tabulated values, the addition of pressure rate and volume rate equations reduces the CPU execution time considerably for small disturbances. However, as the sea state is increased the CPU time increases. Apparently other factors in the program begin to dominate the total execution time.

TABLE III

TIMING QUALITY FACTORS

20 Knots

	Program One	Program Two	Program Three
Condition One	11.25	4.8	4.50
Condition Two	13.85	6.0	5.50
Condition Three	23.0	20.5	19.2
Condition Four	42.8	28.01	22.0
Condition Five	71.0	58.1	54.0

TABLE IV

TIMING QUALITY FACTORS

30 Knots

	Program One	Program Two	Program Three
Condition One	10.8	7.5	4.5
Condition Two	18.0	14.25	8.7
Condition Three	24.0	22.0	21.0
Condition Four	45.0	30.0	28.0
Condition Five	75.0	59.2	53.0

This supports the results of Reference (7) that for sea conditions the bulk of computation time is apparently in the SUBROUTINE WAVES.

It was observed that at irregular sea state two and regular sea state three water came in contact with the top of the plenum. The L&M program does not include the effect of this phenomenon in the program simulation; therefore, testing was not conducted at higher sea state conditions. The fact that water hits the top of the plenum is a reasonable condition under certain circumstances. For example, if the pitch angle is 3 degrees up the stern sinks over 6 inches. If the draft of the craft at that time is 11 inches and if the preceding wave passing the stern station is 5 inches, water should hit the top of the plenum at the stern station. The effect of this condition on total craft behavior in terms of forces and moments is not known. The effect of water contact would depend upon such factors as the length of time the wave is in contact with the top of the plenum and the area of the plenum in contact with the wave.

B. INCREASING WAVE COMPONENTS

Tests were made for irregular seas one and two using 8, 10, 15, and 20 wave components. No apparent change in output could be determined. The time at which changes in output occurred changed, but no significant reduction in output values were noted; that is the time when wave components were in-phase or out-of-phase was different, but the craft response

was the same. It was felt that if more components were used, the energy (in this case, the magnitude and frequency of the disturbing force) would be distributed over many components and that the irregular combination of these components would spread the energy of the disturbance over a larger time base. This spreading of the energy would then reduce the magnitude of the disturbance and that in turn would provide less rapid rates of change. With less rapid changes in the disturbances, the integration would take less time. The over-all time increase due to more wave components would be offset by the reduction in integration time. This is not the case; using more wave components increased CPU time. Whether 10 or less wave components are sufficient to accurately represent irregular seas was not tested.

C. MEMBRANE MODELS

A large amount of time was expended in attempting to provide adquate modeling of the plenum membrane. Model One using $V_m = K\ P_b$ in PROGRAM ONE did not work at all. The program would begin to execute and then stop when the integration step size was less than 1×10^{-6}.

As an aid to find the reason for this failure a computational flow diagram was drawn (See Figure 1). The addition of the correction term V_m creates an algebraic inner loop as shown by the dashed line in Fig. 1. Using a small perturbation of D in calm water and using the print switches in RHS as well as using the DEBUG option available with the G compiler, it

was observed that with Model One the values of pressure were divergent. It is not known why pressure values diverge; however, it was noted that at certain times the values of pressure and volume were increasing or decreasing together, that is when pressure was increasing while volume was increasing.

The computational flow diagram for Model Two (Figure 2) shows the inner connections of the pressure, volume and mass variables. Model Two exhibited the same symptoms and the same results as Model One, except in some cases pressure rate and volume rate rose or fell together at the same time step.

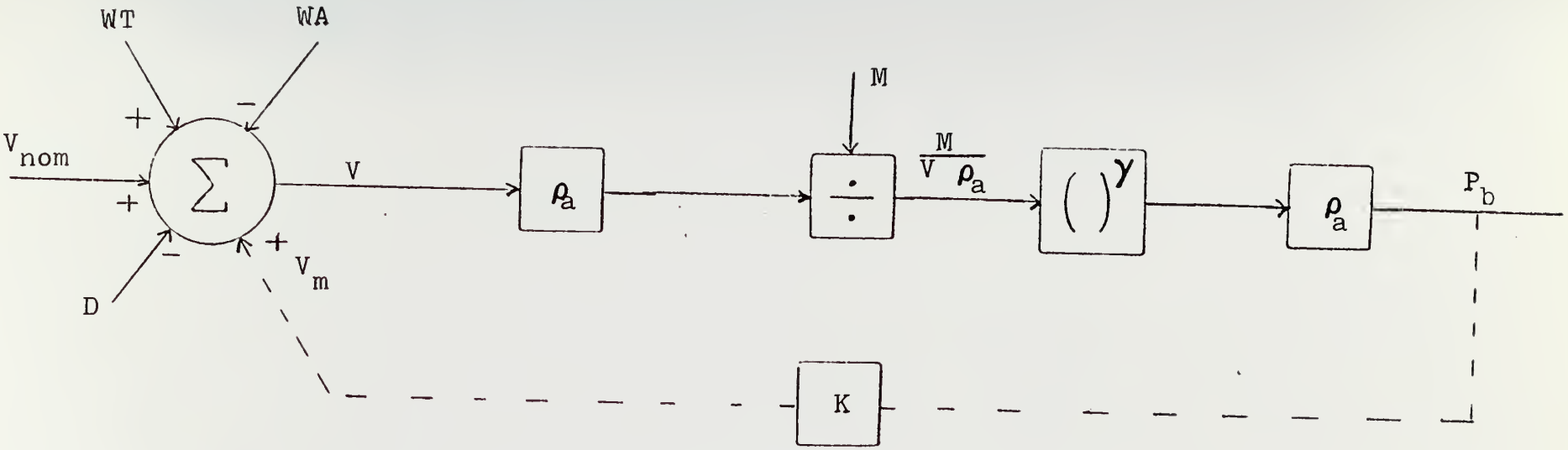
The failures of Model One and Two led to Model Three. It was felt that by correcting both pressure rate and volume rate the divergence exhibited in Models One and Two could be corrected. Model Three also failed; however, it provided the motivation to consider mass rate into the membrane. The computations performed in Model Three is shown in Figure 3.

Model Four was marginally successful. The program executes and slightly reduces the center of gravity acceleration. the reduction of the center of gravity acceleration was chosen as the criterion of whether the model was representing the membrane. This model was tested in sea state one and sea state two and provides slight reduction in the maximum values in the center of gravity acceleration. It did not reduce all of the center of gravity values. The computational flow diagram

of Model Four is given in Figure 4 and shows no algebraic loops in the RHS computations of pressure and volume rates.

Model Five was the most successful model. The computational flow is shown in Figure 5. Model Five reduced the center of gravity acceleration and for small disturbances, the pitch angle and pitch rate. For sea state one a significant reduction was observed. (See Figures 6 and 7). However, for sea state two the center of gravity accelerations were greater for the membrane when compared to the no membrane case. (See Figures 8 and 9). No reason for this could be found. The only differences in these two runs was the sea state.

One possible reason for the sea state two results, though not yet proven, could be a resonance effect at the sea state encounter frequency. Concurrent work in this area [Ref. 14] investigates the conditions for the existence of any resonance phenomena. Preliminary investigations indicate that at a wave encounter frequency of approximately 4 rad / second resonance in pitch angle occurs. The encounter frequency for regular sea state two is 5 rad / second. Whether resonance phenomena could cause this effect, however, was not determined.



(All values shown for the K^{th} iteration in RHS)

Figure 1. Computational Flow Diagram Model I

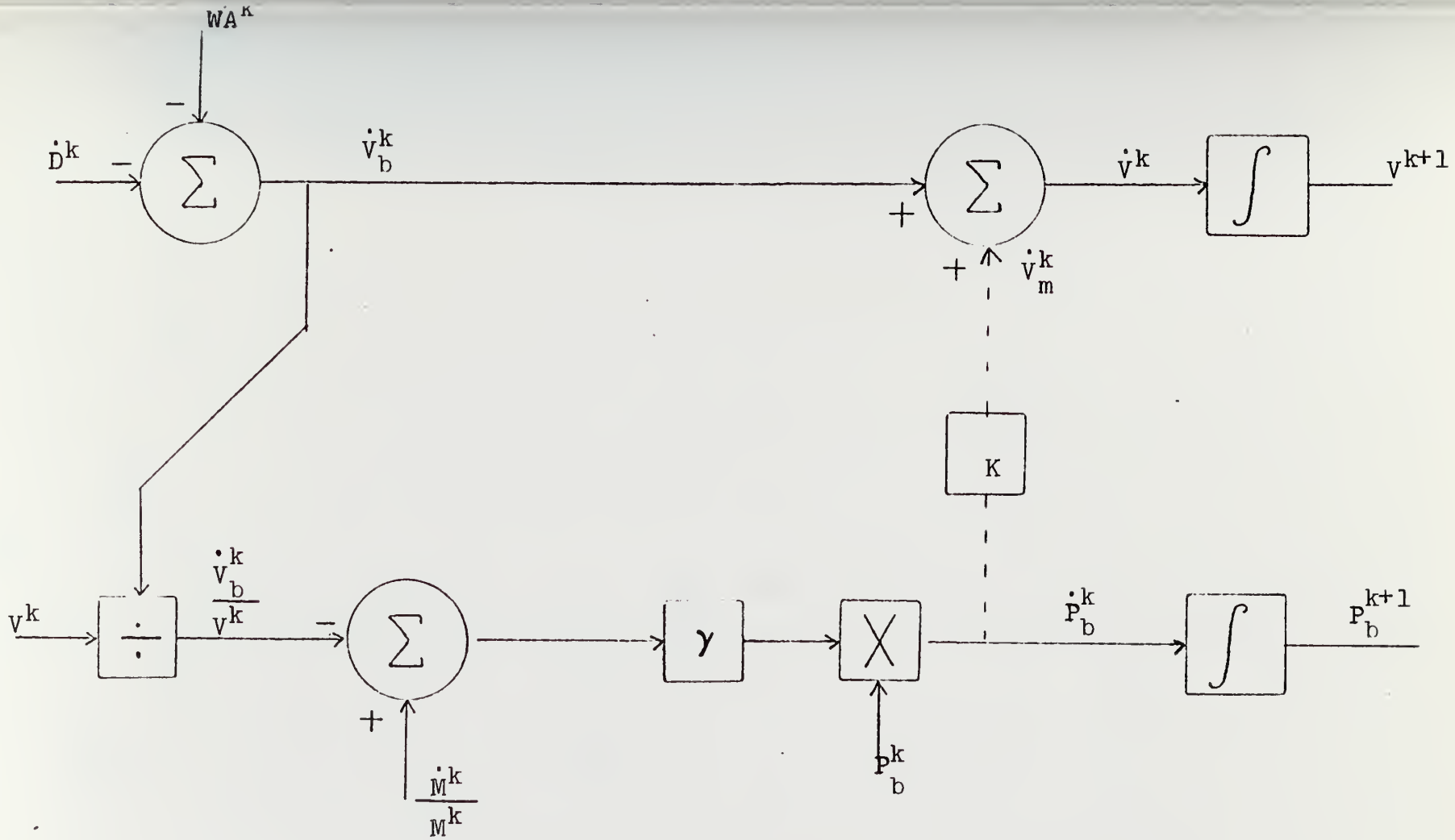


Figure 2. Computational Flow Diagram Model II

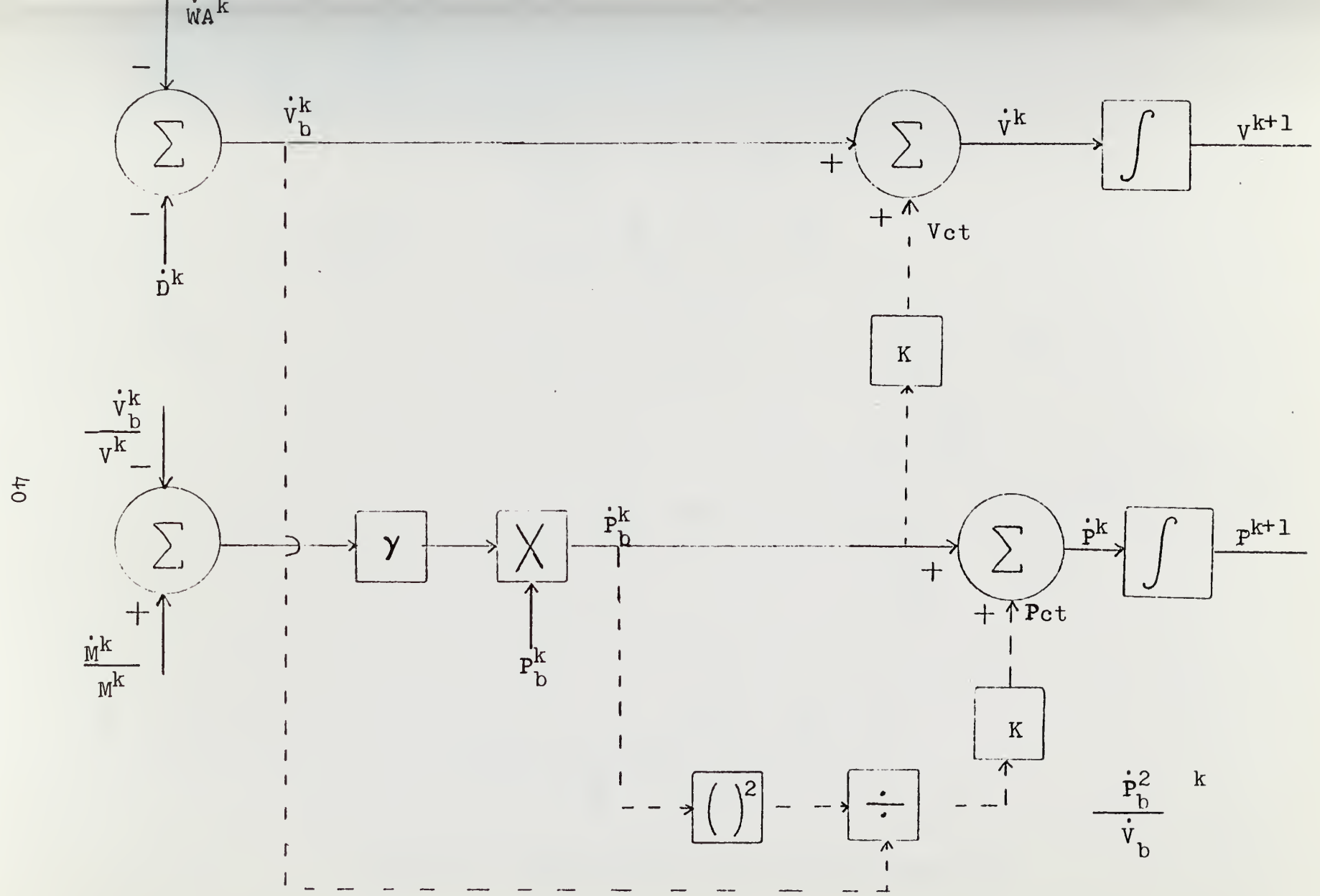


Figure 3. Computational Flow Diagram Model III

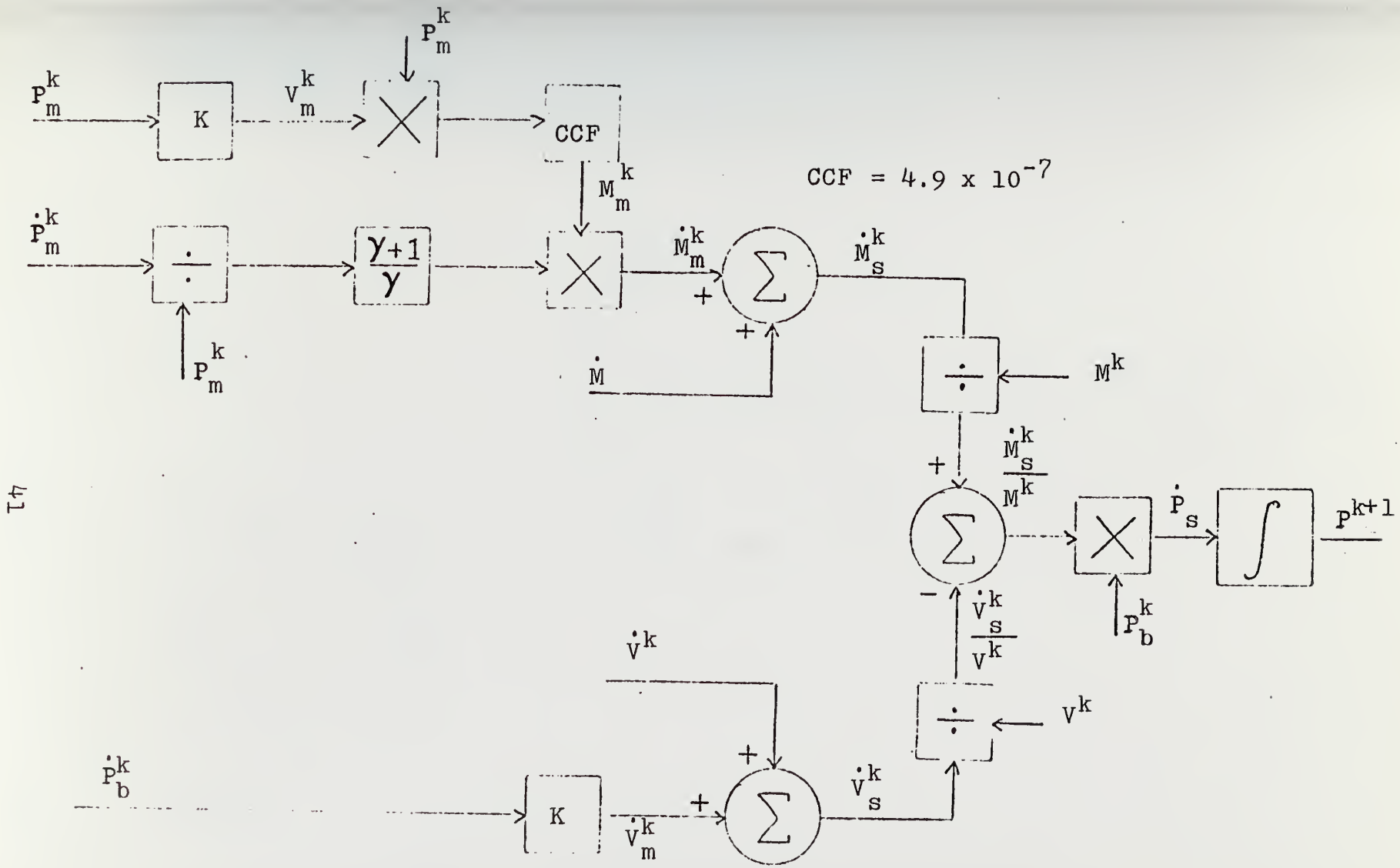


Figure 4. Computational Flow Diagram Model IV

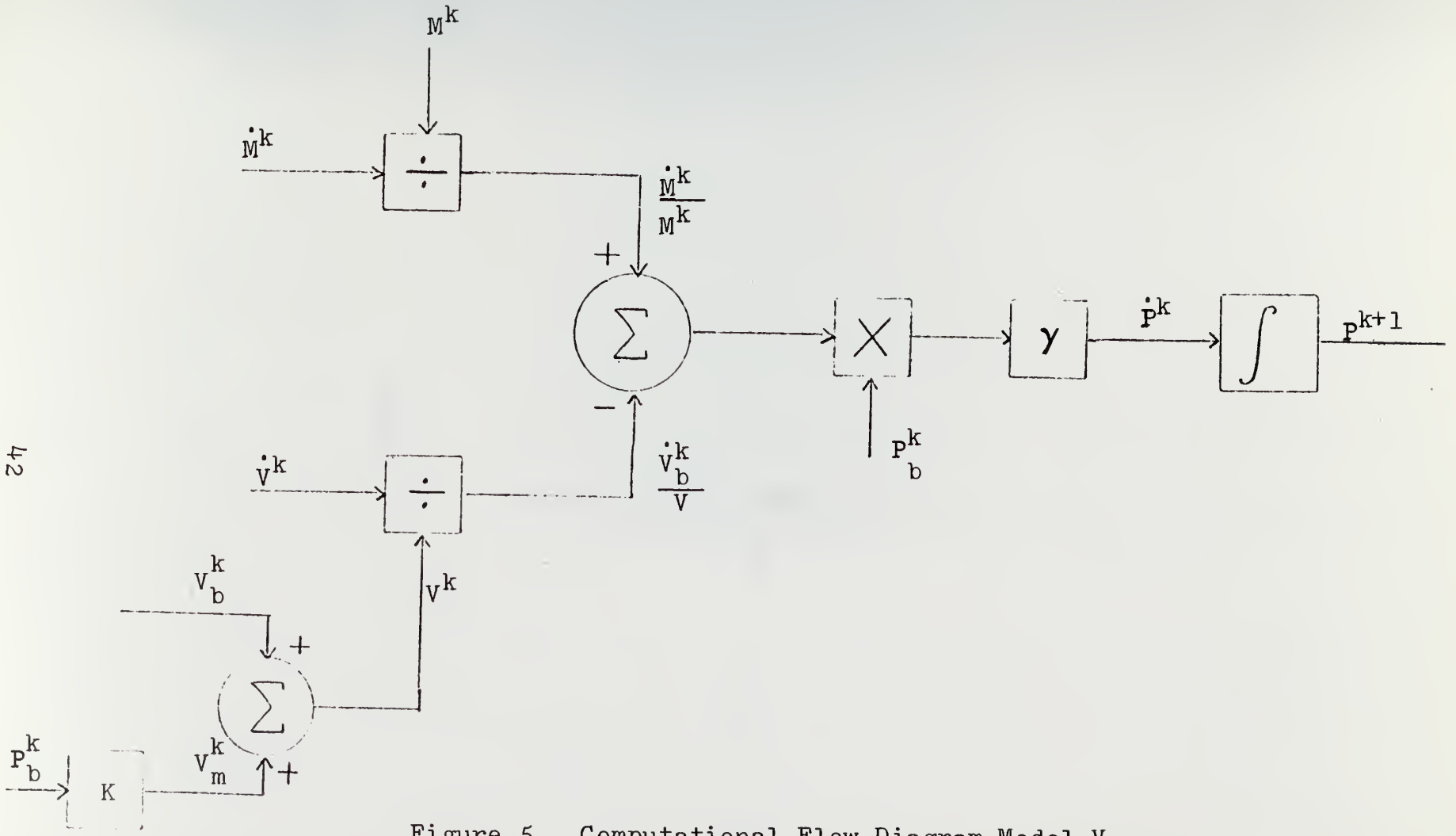


Figure 5. Computational Flow Diagram Model V

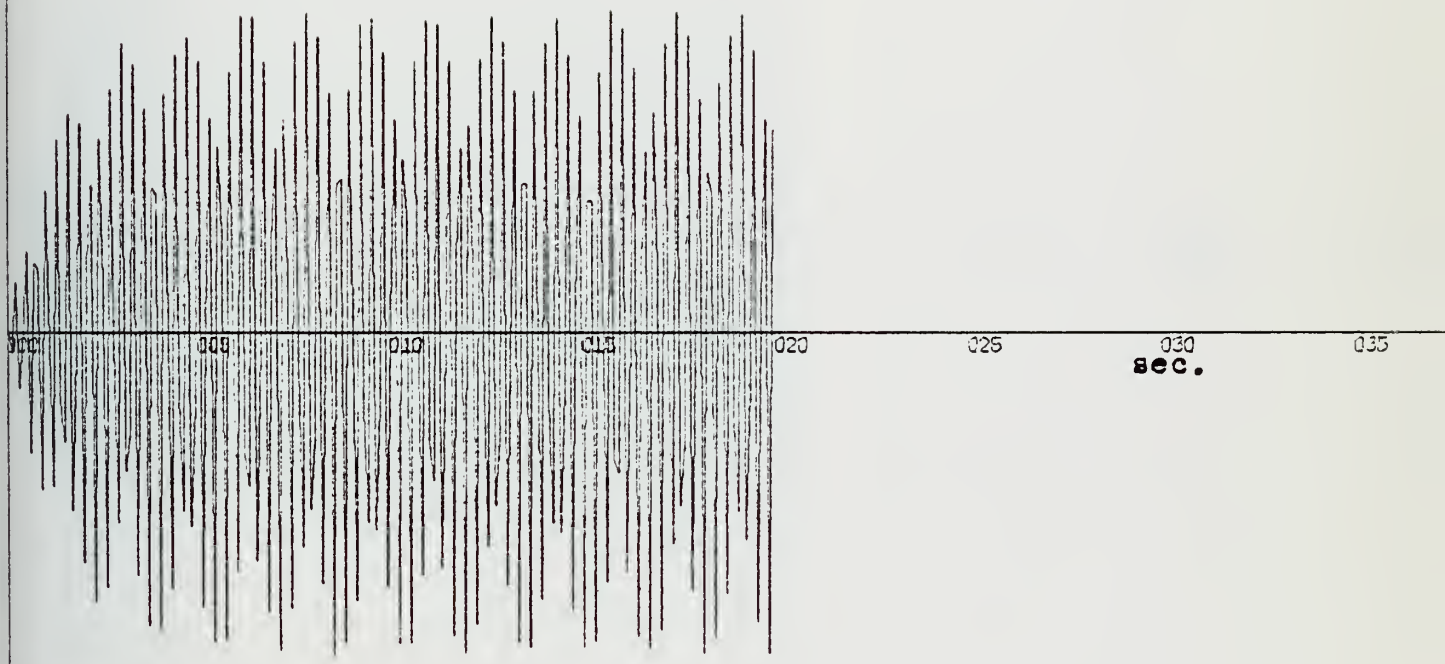


FIGURE 6

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=5.00E-02 UNITS INCH.
PROGRAM 2 MODEL 5 20KTS REG. SEA 1
PLOT IS C.G.ACCELERATION VERSUS TIME

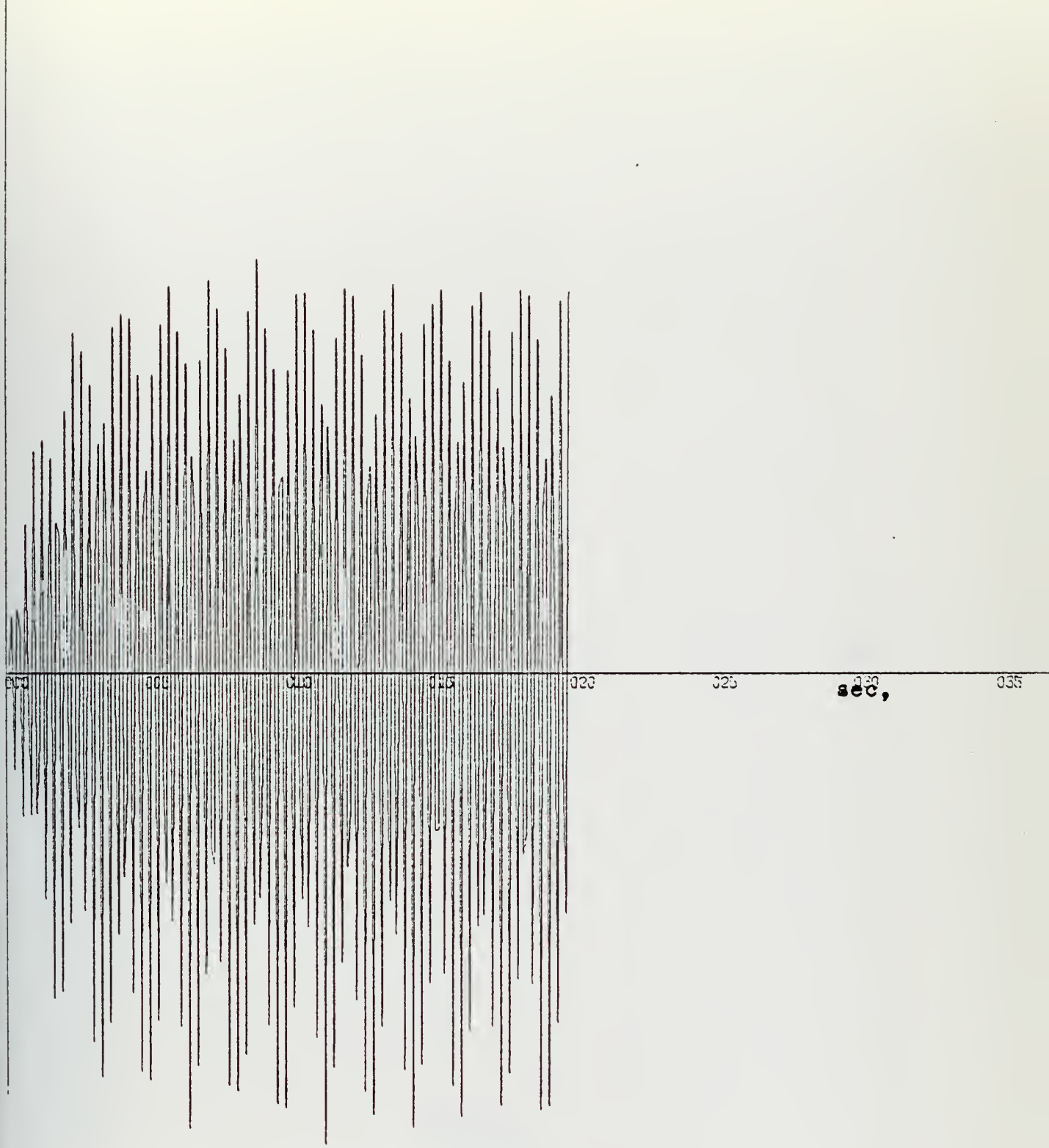


FIGURE 7

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=5.00E-02 UNITS INCH.
PROGRAM 2 WITHOUT MEMBRANE REG. SEA 1
PLOT IS C.G.ACCELERATION VERSUS TIME

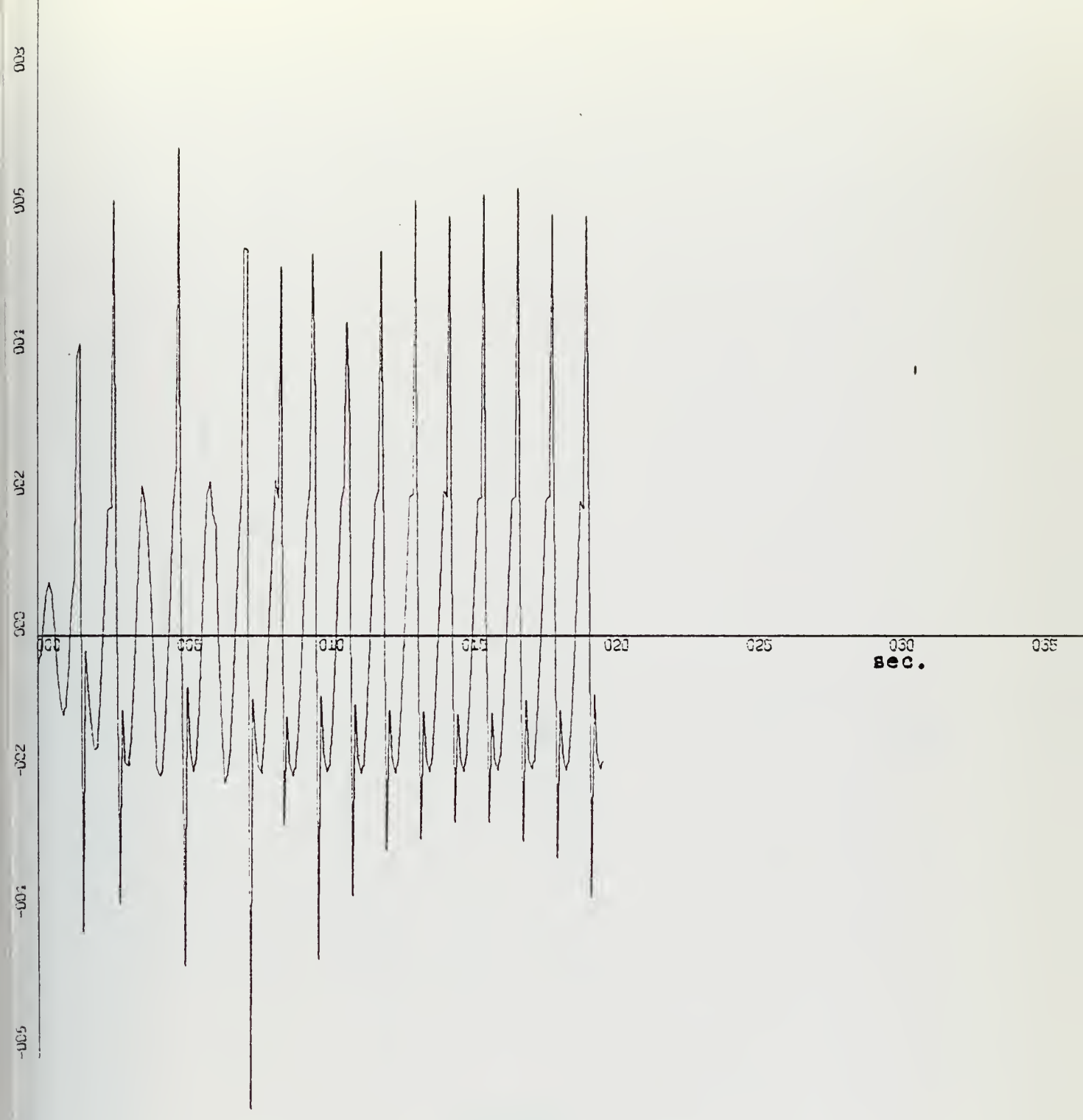


FIGURE 8

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
PROGRAM 2 MODEL 5 20KTS REG. SEA 2
PLOT IS C.G.ACCELERATION VERSUS TIME

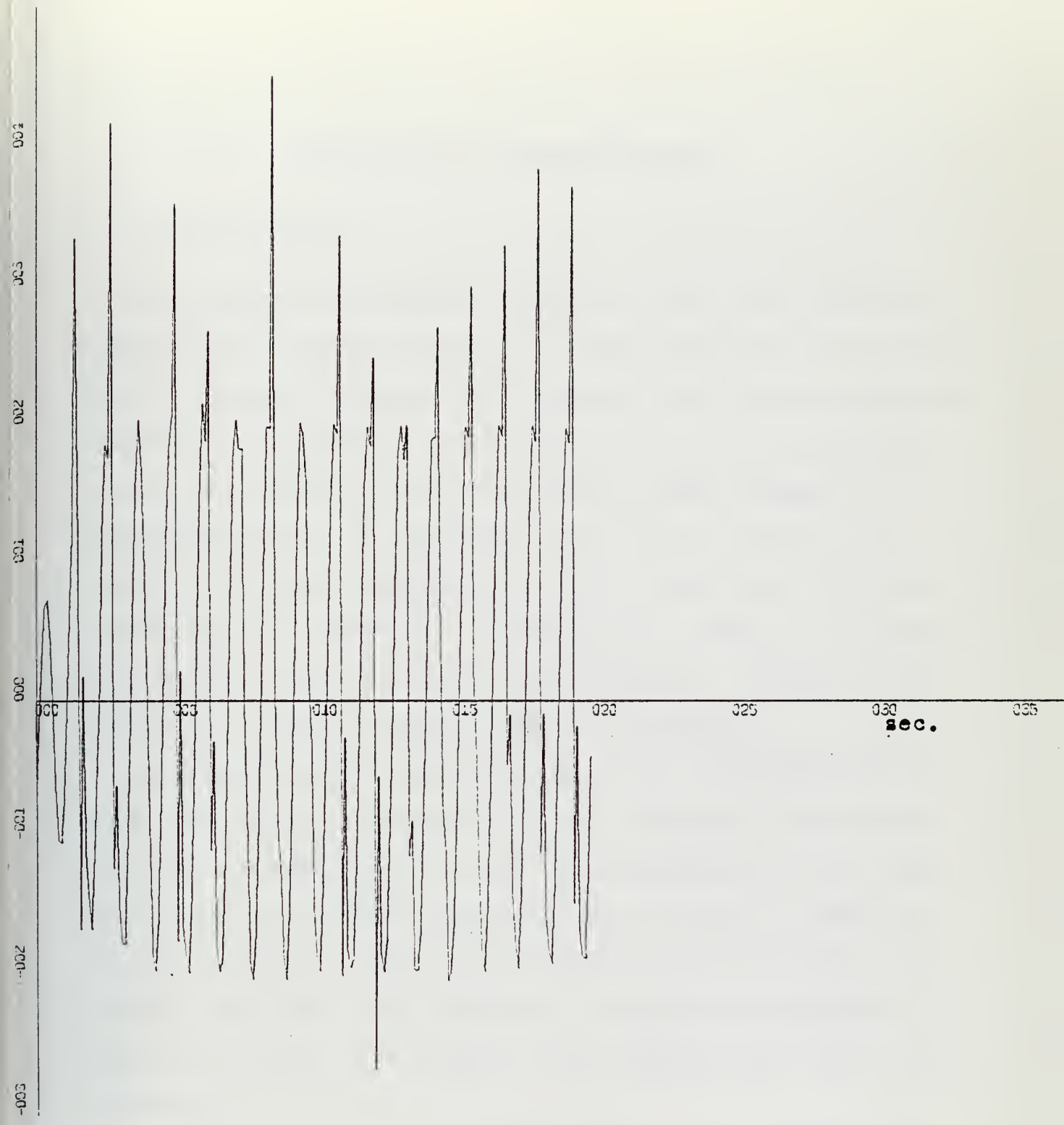


FIGURE 9

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
PROGRAM 2 WITHOUT MEMBRANE REG. SEA 2
PLOT IS C.G.ACCELERATION VERSUS TIME

VI. CONCLUSIONS AND RECOMMENDATIONS

A. PROGRAM TIMING

The inclusion of pressure rate and volume rate equations improved the execution time of the L&M program without decreasing the program accuracy. The changes to the program were not difficult to implement. Further effort to improve execution time of the program should be directed toward changes to SUBROUTINE WAVES. In connection with this, a study of the number of required sidewall and bow and stern seal stations should also be conducted. By reducing the number of sidewall stations the execution time should decrease. A study of the losses in accuracy, however, would be necessary.

Another facet for investigation within SUBROUTINE WAVES would be a study to determine if the trignometric functions could be represented by the in-line programming of the expansion of sine and cosine functions, vice the use of computer library functions. Since some sine and cosine functions are nested in DO LOOPS small savings in time would accumulate. Again, the losses in accuracy to this change would have to be determined.

The elimination of SUBROUTINE DMINV did not produce any noticeable time savings but did save approximately 2 K bytes of core.

The expansion of the number of wave components did not demonstrate any time savings; however the optimum number of wave components required to simulate irregular sea conditions should be determined. A possible course of action would be to generate wave components, calculate the magnitude and frequency and compute the energy spectral density. This energy density spectrum could then be compared to the Pierson and Neumann or Moskowitz model [Ref. 11]. By determining the optimum number of wave components, a savings in CPU execution time could result.

B. ADDITIONAL MODELING

The fact that waves can hit the top of the plenum was discussed in Section V. Whether this effect produces significant forces and moments is unknown. Since the time that the wave is in contact with the plenum and the location (station numbers) is known and since the area of the plenum in contact with the waves could be approximated, (no greater than the difference between wetted stations) additional correction terms could be developed to determine whether significant forces and moments are generated by wave contact. The drag of the wetted plenum top could also be considered.

C. MEMBRANE MODELING

Of the five membrane models developed in this study, Model Five is the most usable. The accuracy of this model must be determined and the model must be validated. Whether

mass and mass flow rate terms could improve this model also needs to be determined. In this regard a detailed study of adiabatic-reversible unsteady flow conditions would be useful. This would mean the establishment of a suitable control volume and the solution of energy-work equations.

The membrane modeling in this study was for a continuous non-permeable membrane. Additional modeling for the case of a hole cut into the membrane should be attempted. The equation for a sharp-edge orifice could be used to determine air loss. The area (size) of the hole can be determined by considering as a first approximation the ratio of surface area of a hemisphere to volume of the hemisphere. As an alternative, the experimental results of the towing tank tests conducted at NSRDC, on the XR-1, using suitable scale factors, could be used to determine empirical correction factors to be applied to the Loads and Motion program.

The occurrences of algebraic loops and summation of feed forward terms as shown in the computational flow diagrams and the failure of the models in which they occur indicate that further modeling of the membrane is required. To prevent model failures, elimination of the effects of the computational loops appears to be necessary.

APPENDIX A

MEMBRANE SCALE FACTOR

The empirical relationship between pressure and volume for the membrane given in Ref. 9 is for the XR-1 test craft.

$$V_m = K P_m \tag{A1}$$

where

$$K = \frac{40 \text{ in}^3}{\text{Psf}}$$

It was therefore necessary to scale the constant K for the XR-3 test craft.

In the following development the subscript 1 refers to the XR-1 and subscript 3 refers to XR-3.

Since XR-1 and XR-3 are similar it was assumed that all dimensions scale by the ratio of plenum lengths

$$\frac{L_3}{L_1} = \lambda \tag{A2}$$

where

$L_3 = 20$ ft.

$L_1 = 5.4$ ft.

It was assumed that the ratio of mass to volume was constant

$$\frac{M_1}{V_1} = \frac{M_3}{V_3} = \rho \tag{A3}$$

The ratio of craft volume is

$$\frac{V_3}{V_1} = \lambda^3 \tag{A4}$$

The ratio of craft pressure is

$$\frac{P_3}{P_1} = \frac{M_{3g}/A_3}{M_{1g}/A_1} \tag{A5}$$

where g is the gravitational constant.

Substituting (A2) and (A3) into (A5)

$$\frac{P_3}{P_1} = \frac{V_3\ A_1}{V_1\ A_3} = \frac{\lambda^3}{\lambda^2} = \lambda \tag{A6}$$

Using (A4) and (A6) in (A1)

$$K_1 = \frac{V_1}{P_1}\ \frac{V_3/\lambda^3}{P_3/\lambda} = \frac{K_3}{\lambda^2} \tag{A7}$$

$$K_3 = \lambda^2 K_1 \tag{A8}$$

Converting in.^{3} to ft.^{3} and using (A2)

$$K_3 = \left(\frac{20}{5.4}\right)^2\ \frac{40}{1728} = .3175\ \text{ft.}^3/\text{psf} \tag{A9}$$

APPENDIX B

LISTING OF FORTRAN XR-3

L&M COMPUTER PROGRAM

PROGRAM TWO MODEL FIVE

```
      INTEGER ON                                                                MAIN   10
      COMMON /AIR/ PINF,RHOINF,GAM                                              MAIN   20
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY         MAIN   30
      COMMON /CONST/ PI,RAD,UO                                                  MAIN   40
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIPMAIN   50
     1(25),TIS(25)                                                              MAIN   60
      COMMON /EQNCO/ NEQS,TOL(20),JQQ                                           MAIN   70
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP                                    MAIN   80
      COMMON /FROUDE/ FN,FNCRIT                                                 MAIN   90
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                             MAIN  100
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  MAIN  110
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IMAIN  120
     1RUD,IPROP,IAEROD,IRHS                                                     MAIN  130
      COMMON /ROLL/ PHIMAX,TROLL                                                MAIN  140
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,RMAIN  150
     1CLB,RTC,RUDANG,TIR(25)                                                    MAIN  160
      COMMON /VALOLD/ YOLD(20)                                                  MAIN  170
      COMMON /VARBLE/ VAL(40)                                                   MAIN  180
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYMAIN  190
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBMAIN  200
     2BAR                                                                       MAIN  210
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6MAIN  220
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(MAIN  230
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB),MAIN  240
     3 (VAL(12),VOL)                                                            MAIN  250
      DIMENSION DUMMY(20)                                                       MAIN  260
      TC = 1.0                                                                  MAIN  270
      ON = 1                                                                    MAIN  280
      PI = 4.*ATAN(1.)                                                          MAIN  290
      RAD = 180./PI                                                             MAIN  300
      WRITE (6,12)                                                              MAIN  310
    1 READ (44,13,END=2) DUMMY                                                  MAIN  320
      WRITE (6,14) DUMMY                                                        MAIN  330
      WRITE (5,13) DUMMY                                                        MAIN  340
      GO TO 1                                                                   MAIN  350
    2 REWIND 5                                                                  MAIN  360
    3 CALL INCON (TIME)                                                         MAIN  370
      IF (IMM.EQ.3) GO TO 11                                                    MAIN  380
      VAL(13) = VAL(24)                                                         MAIN  390
C                                                                               MAIN  400
      DO 4 J=1,20                                                               MAIN  410
    4 YOLD(J) = VAL(J+1)                                                        MAIN  420
C                                                                               MAIN  430
      GO TO 8                                                                   MAIN  440
    5 CONTINUE                                                                  MAIN  450
      TOLD = TIME                                                               MAIN  460
      PBBAR = PBBAR*(1.-DELT/TC)+DELT*(PB-PINF)/TC                              MAIN  470
```

```
      IF (NWAVE.LE.0) GO TO 6                                          MAIN 480
      ZBAR = (1.-DELT/TC)*ZBAR+DELT*Z/TC                               MAIN 490
      PHIBAR = (1.-DELT/TC)*PHIBAR+DELT*PHI/TC                         MAIN 500
      THEBAR = (1.-DELT/TC)*THEBAR+DELT*THETA/TC                       MAIN 510
      CALL WAVES (TIME)                                                MAIN 520
    6 CALL SIDEWL                                                      MAIN 530
      CALL PROP                                                        MAIN 540
      CALL RUDDER                                                      MAIN 550
      CALL AEROD                                                       MAIN 560
      CALL INTGRL (TIME)                                               MAIN 570
      IF (TIME.GT.FTIME) GO TO 10                                      MAIN 580
      IF (FN.GT.FNCRIT) GO TO 7                                        MAIN 590
      PRINT 17                                                         MAIN 600
      GO TO 10                                                         MAIN 610
    7 DELOLD = TIME-TOLD                                               MAIN 620
      PSI = PSI+DELOLD*R                                               MAIN 630
      X = X+DELOLD*(U*COS(PSI)-V*SIN(PSI))                             MAIN 640
      Y = Y+DELOLD*(U*SIN(PSI)+V*COS(PSI))                             MAIN 650
      IF (ABS(TIME-TPRINT).LT.1.E-6) GO TO 8                           MAIN 660
      GO TO 5                                                          MAIN 670
    8 CONTINUE                                                         MAIN 680
      IF (ITRAJ.EQ.0) GO TO 9                                          MAIN 690
      DPHI = PHI*RAD                                                   MAIN 700
      DPSI = PSI*RAD                                                   MAIN 710
      DTHETA = THETA*RAD                                               MAIN 720
      DP = P*RAD                                                       MAIN 730
      DQ = Q*RAD                                                       MAIN 740
      DR = R*RAD                                                       MAIN 750
      VEL = 0.5925*U                                                   MAIN 760
      WRITE (6,15) TIME,VEL,V,W,DP,DQ,DR,Z,DPHI,DTHETA,X,Y,DPSI        MAIN 770
      BETS = (-V/U)*RAD                                                MAIN 780
      DELRS = RUDANG*RAD                                               MAIN 790
      WRITE (6,16) BETS,DELRS,FXP                                      MAIN 800
    9 CONTINUE                                                         MAIN 810
      IMMTAG = (IMM+1)/2                                               MAIN 820
      IF (IMMTAG.EQ.1.AND.TIME.GE.BTIME-1.E-8) IMT=1                   MAIN 830
      TPRINT = TPRINT+DELPNT                                           MAIN 840
      CN = 1                                                           MAIN 850
      GO TO 5                                                          MAIN 860
   10 CALL COLFIL                                                      MAIN 870
      IF (IMM.LT.1) GO TO 3                                            MAIN 880
      IF (IMM.NE.1) GO TO 11                                           MAIN 890
      END FILE IBMFIL                                                  MAIN 900
      GO TO 3                                                          MAIN 910
   11 CALL SAM                                                         MAIN 920
      GO TO 3                                                          MAIN 930
C                                                                      MAIN 940
   12 FORMAT (1H1//35X,22H LISTING OF INPUT DECK//)                    MAIN 950
```

```
   13 FORMAT (20A4)                                                                MAIN  960
   14 FORMAT (5X,20A4)                                                             MAIN  970
   15 FORMAT (//10X,13HTIME (SEC) = F6.2//10X,33HTRANSLATIONAL VELS (KTSMAIN  980
     1)/(FT/SEC)/10X,2HU=F6.2,5X,2HV=F6.2,5X,2HW=F6.3//10X,31HROTATIONALMAIN  990
     2 VELOCITIES (DEG/SEC)/10X,2HP=F6.2,5X,2HQ=F6.2,5X,2HR=F6.2//10X,30MAIN 1000
     3HDISPLACEMENTS (FT AND DEGREES)/10X,2HZ=F7.3,5X,4HPHI=F6.2,3X,6HTHMAIN 1010
     4ETA=F6.2//10X,27HTRAJECTORY (FT AND DEGREES)/10X,2HX=F8.2,4X,2HY=FMAIN 1020
     58.2,4X,4HPSI=F8.2)                                                         MAIN 1030
   16 FORMAT (1H0,9X,23HSIDESLIP ANGLE (DEG) = F8.2,10X,21HRUDDER ANGLE MAIN 1040
     1(DEG) = F8.2,10X,15HTHRUST (LBS) = F12.1)                                  MAIN 1050
   17 FORMAT (///25X,28HCRAFT SPEED BELOW HUMP SPEED)                            MAIN 1060
      END                                                                        MAIN 1070

      SUBROUTINE AEROD                                                           AER   10
C                                                                                AER   20
      INTEGER ON                                                                 AER   30
      COMMON /FAERO/ FX,FY,FZ,FK,FM,FN                                           AER   40
      COMMON /FAIR/ RHOA,XLAERO                                                  AER   50
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7           AER   60
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IAER   70
     1RUD,IPROP,IAEROD,IRHS                                                      AER   80
      COMMON /VARBLE/ VAL(40)                                                    AER   90
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6AER  100
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(AER  110
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)  AER  120
C                                                                                AER  130
      QA = RHOA*U*U                                                              AER  140
      QAL = QA*XLAERO                                                            AER  150
      BETA = -V/U                                                                AER  160
      BETASQ = BETA*BETA                                                         AER  170
      FX = -(0.90*BETASQ+0.13)*QA                                                AER  180
      FY = (0.0*BETASQ+0.53*BETA)*QA                                             AER  190
      FZ = -(2.06*BETASQ+0.39)*QA                                                AER  200
      FK = -(0.5*BETASQ+0.0*BETA)*QAL                                            AER  210
      FM = (0.29*BETASQ+0.12)*QAL                                                AER  220
      FN = (0.0*BETASQ+0.076*BETA)*QAL                                           AER  230
      IF (IAEROD.NE.ON) RETURN                                                   AER  240
      WRITE (6,1) FX,FY,FZ,FK,FM,FN                                              AER  250
C                                                                                AER  260
C                                                                                AER  270
      RETURN                                                                     AER  280
C                                                                                AER  290
    1 FORMAT (/10X,23HAEROD FX,FY,FZ,FK,FM,FN/6E15.4)                            AER  300
      END                                                                        AER  310

      BLOCK DATA                                                                 BLDA  10
      COMMON /AIR/ Z1(3)                                                         BLDA  20
      COMMON /BMCO/ Z2(25)                                                       BLDA  30
```

```
      COMMON /COLUMN/ Z3(2)                                             BLDA   40
      COMMON /CONST/ Z4(3)                                              BLDA   50
      COMMON /CNTRL/ Z5(10)                                             BLDA   60
      COMMON /ENGINE/ Z6(107)                                           BLDA   70
      COMMON /EQNCO/ Z7(22)                                             BLDA   80
      COMMON /FAERO/ Z8(6)                                              BLDA   90
      COMMON /FAIR/ Z9(2)                                               BLDA  100
      COMMON /FANMAP/ Z10(262)                                          BLDA  110
      COMMON /FORBS/ Z11(7)                                             BLDA  120
      COMMON /FORSS/ Z12(8)                                             BLDA  130
      COMMON /FPROP/ Z13(6)                                             BLDA  140
      COMMON /FROUDE/ Z14(2)                                            BLDA  150
      COMMON /FRUD/ Z15(6)                                              BLDA  160
      COMMON /GBCW/ Z16(1)                                              BLDA  170
      COMMON /GEOM/ Z17(138)                                            BLDA  180
      COMMON /GEOMBS/ Z18(62)                                           BLDA  190
      COMMON /GEOMSS/ Z19(62)                                           BLDA  200
      COMMON /GEOMSW/ Z20(11)                                           BLDA  210
      COMMON /KSWTCH/ Z21(1)                                            BLDA  220
      COMMON /LEAKER/ Z22(4)                                            BLDA  230
      COMMON /MASSES/ Z23(817)                                          BLDA  240
      COMMON /MATRIX/ Z24(36)                                           BLDA  250
      COMMON /MSIDW/ Z25(55)                                            BLDA  260
      COMMON /MWAVE/ Z26(12)                                            BLDA  270
      COMMON /OPTION/ Z27(4)                                            BLDA  280
      COMMON /PLENUM/ Z28(7)                                            BLDA  290
      COMMON /PRIME/ Z29(5)                                             BLDA  300
      COMMON /PRTINT/ Z30(12)                                           BLDA  310
      COMMON /PWAVE/ Z31(2)                                             BLDA  320
      COMMON /RISER/ Z32(1)                                             BLDA  330
      COMMON /ROLL/ Z33(2)                                              BLDA  340
      COMMON /RUDDR/ Z34(62)                                            BLDA  350
      COMMON /SIDE/ Z35(22)                                             BLDA  360
      COMMON /SOFTBS/ Z36(20)                                           BLDA  370
      COMMON /SOFTSS/ Z37(19)                                           BLDA  380
      COMMON /STABLE/ Z38(5)                                            BLDA  390
      COMMON /STSLR/ Z39(2)                                             BLDA  400
      COMMON /VALOLD/ Z40(20)                                           BLDA  410
      COMMON /VARBLE/ Z41(40)                                           BLDA  420
      COMMON /WAVE/ Z42(100)                                            BLDA  430
      COMMON /WAVEF/ Z43(80)                                            BLDA  440
      COMMON /SLOPE/ Z44(5)                                             BLDA  450
      COMMON /PROMOD/ Z45(7)                                            BLDA  460
      DATA Z1/3*0.0/                                                    BLDA  470
      DATA Z2/25*0.0/                                                   BLDA  480
      DATA Z3/2*0.0/                                                    BLDA  490
      DATA Z4/3*0.0/                                                    BLDA  500
      DATA Z5/10*0.0/                                                   BLDA  510
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      DATA Z6/107*0.0/                                                  BLDA  520
      DATA Z7/21*0.0/                                                   BLDA  530
      DATA Z8/6*0.0/                                                    BLDA  540
      DATA Z9/2*0.0/                                                    BLDA  550
      DATA Z10/262*0.0/                                                 BLDA  560
      DATA Z11/7*0.0/                                                   BLDA  570
      DATA Z12/8*0.0/                                                   BLDA  580
      DATA Z13/6*0.0/                                                   BLDA  590
      DATA Z14/2*0.0/                                                   BLDA  600
      DATA Z15/6*0.0/                                                   BLDA  610
      DATA Z16/0.0/                                                     BLDA  620
      DATA Z17/138*0.0/                                                 BLDA  630
      DATA Z18/62*0.0/                                                  BLDA  640
      DATA Z19/62*0.0/                                                  BLDA  650
      DATA Z20/11*0.0/                                                  BLDA  660
      DATA Z21/0.0/                                                     BLDA  670
      DATA Z22/4*0.0/                                                   BLDA  680
      DATA Z23/817*0.0/                                                 BLDA  690
      DATA Z24/36*0.0/                                                  BLDA  700
      DATA Z25/55*0.0/                                                  BLDA  710
      DATA Z26/12*0.0/                                                  BLDA  720
      DATA Z27/4*0.0/                                                   BLDA  730
      DATA Z28/7*0.0/                                                   BLDA  740
      DATA Z29/5*0.0/                                                   BLDA  750
      DATA Z30/12*0.0/                                                  BLDA  760
      DATA Z31/2*0.0/                                                   BLDA  770
      DATA Z32/0.0/                                                     BLDA  780
      DATA Z33/2*0.0/                                                   BLDA  790
      DATA Z34/62*0.0/                                                  BLDA  800
      DATA Z35/22*0.0/                                                  BLDA  810
      DATA Z36/20*0.0/                                                  BLDA  820
      DATA Z37/19*0.0/                                                  BLDA  830
      DATA Z38/5*0.0/                                                   BLDA  840
      DATA Z39/2*0.0/                                                   BLDA  850
      DATA Z40/20*0.0/                                                  BLDA  860
      DATA Z41/40*0.0/                                                  BLDA  870
      DATA Z42/100*0.0/                                                 BLDA  880
      DATA Z43/80*0.0/                                                  BLDA  890
      DATA Z44/5*0.0/                                                   BLDA  900
      DATA Z45/7*0.0/                                                   BLDA  910
      END                                                               BLDA  920

      SUBROUTINE BOWSL                                                  BWSL   10
C                                                                       BWSL   20
      INTEGER CN                                                        BWSL   30
      COMMON /AIR/ PINF,RHOINF,GAM                                      BWSL   40
      COMMON /CONST/ PI,RAD,UO                                          BWSL   50
      COMMON /FORBS/ FX,FY,FZ,FK,FM,FN,QL                               BWSL   60
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      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,BWSL   70
     110),XCP,ZCP                                                       BWSL   80
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)BWSL   90
     1,TSKIB(10)                                                        BWSL  100
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS                             BWSL  110
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMBWSL  120
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         BWSL  130
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IBWSL  140
     1RUD,IPROP,IAEROD,IRHS                                             BWSL  150
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  BWSL  160
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    BWSL  170
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVBWSL  180
     1GB(10),CENCAB                                                     BWSL  190
      COMMON /VARBLE/ VAL(40)                                           BWSL  200
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYBWSL  210
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBWSL  220
     2BAR                                                               BWSL  230
      DIMENSION ELSKID(11), WETLEN(11), BWSL(6,24), GAP(11), ELSKI(11), BWSL  240
     1DPFT(11)                                                          BWSL  250
      DATA ENU,HINGHT/1.28E-5,1.875/                                    BWSL  260
      DATA BWSL/0.0,3.8,6.9,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.0BWSL  270
     1,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12.BWSL  280
     24,15.4,18.3,0.0,5.5,9.6,13.3,16.1,19.6,0.0,5.8,9.9,13.8,17.1,20.6,BWSL  290
     30.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,11BWSL  300
     4.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,24BWSL  310
     5.1,28.3,0.0,8.2,15.3,21.7,26.3,31.3,0.0,9.6,17.5,24.2,29.7,34.6,0.BWSL  320
     60,11.9,20.0,26.7,32.3,38.0,0.0,14.0,22.5,30.0,35.8,41.0,0.0,17.5,2BWSL  330
     75.5,32.5,39.7,44.5,0.0,21.0,30.0,37.4,42.0,47.0,0.0,24.6,33.7,41.0BWSL  340
     8,45.0,48.7,0.0,29.4,38.5,45.0,48.7,48.7,0.0,33.0,45.0,48.7,48.7,48BWSL  350
     9.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,4BWSL  360
     $8.7,48.7,48.7,48.7,48.7/                                          BWSL  370
      DATA CORLEN/3.75/                                                 BWSL  380
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VABWSL  390
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VABWSL  400
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)BWSL  410
     3, (VAL(24),PB)                                                    BWSL  420
C                                                                       BWSL  430
C                                                                       BWSL  440
      DO 1 J=1,11                                                       BWSL  450
      GAP(J) = 0.0                                                      BWSL  460
      ELSKI(J) = 0.0                                                    BWSL  470
      WETLEN(J) = 0.0                                                   BWSL  480
      ELSKID(J) = 0.0                                                   BWSL  490
    1 CONTINUE                                                          BWSL  500
C                                                                       BWSL  510
      ALBS = 0.0                                                        BWSL  520
      FX = 0.0                                                          BWSL  530
      FZ = 0.0                                                          BWSL  540
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      FK = 0.0                                                                  BWSL 550
      FM = 0.0                                                                  BWSL 560
      FN = 0.0                                                                  BWSL 570
      DELPBG = PBS-PB                                                           BWSL 580
      IF (DELPBG.LT.0.0) DELPBG=0.0                                             BWSL 590
      PBAR = PB-PINF                                                            BWSL 600
      DELP = PBAR                                                               BWSL 610
      IF (DELP.LT.0.0) DELP=0.0                                                 BWSL 620
      ARGO = ELMAXB/CORLEN                                                      BWSL 630
      ANGO = ARSIN(ARGO)                                                        BWSL 640
      X1 = XBS+ZBS*THETA-CORLEN*COS(ANGO)                                       BWSL 650
      Z1 = -Z-ZBS+XBS*THETA-ELMAXB*COS(THETA)                                   BWSL 660
      DPTHFT = (5.5/(1.+(U/25.))**2)*0.0833                                     BWSL 670
      IF (CENCAB.GT.1.1875) CENCAB=1.1875                                       BWSL 680
      N = NSTA(3)                                                               BWSL 690
C                                                                               BWSL 700
      DO 3 K=1,N                                                                BWSL 710
      DPFT(K) = DPTHFT                                                          BWSL 720
      ELSKI(K) = (ETA(3,K)-DETABX(K)*(XX(3,K)-X1)-Z1)+YY(3,K)*PHI+XLXPWVBWSL 730
     1*WATSLP                                                                   BWSL 740
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT                                   BWSL 750
      IF ((HINGHT-ELSKI(K)+DPFT(K)).GE.ELMAXB) DPFT(K)=ELMAXB-HINGHT+ELSBWSL 760
     1KI(K)                                                                     BWSL 770
      IF (DPFT(K).LT.0.0) DPFT(K)=0.0                                           BWSL 780
      ELSKID(K) = (ELSKI(K)-DPFT(K))*12.0                                       BWSL 790
      IF ((HINGHT-ELSKID(K)/12.0).GE.ELMAXB) ELSKID(K)=(HINGHT-ELMAXB)*1BWSL 800
     12.0                                                                       BWSL 810
      DPIN = DPFT(K)*12.0                                                       BWSL 820
      MM = DPIN                                                                 BWSL 830
      MM1 = MM+1                                                                BWSL 840
      MM2 = MM1+1                                                               BWSL 850
      DINC = DPIN-MM                                                            BWSL 860
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXB)                                        BWSL 870
      IF (GAP(K).LT.0.0) GAP(K)=0.0                                             BWSL 880
      IF (ELSKID(K).GE.0.) GO TO 2                                              BWSL 890
      WETLEN(K) = ELSKI(K)                                                      BWSL 900
      GO TO 3                                                                   BWSL 910
    2 MM3 = ELSKID(K)                                                           BWSL 920
      MM4 = MM3+1                                                               BWSL 930
      MM5 = MM4+1                                                               BWSL 940
      DLINC = ELSKID(K)-MM3                                                     BWSL 950
      BWSL1 = BWSL(MM1,MM4)                                                     BWSL 960
      BWSL2 = BWSL(MM1,MM5)                                                     BWSL 970
      BWSL3 = BWSL(MM2,MM4)                                                     BWSL 980
      BWSL4 = BWSL(MM2,MM5)                                                     BWSL 990
      BWSLA1 = (BWSL2-BWSL1)*DLINC+BWSL1                                        BWSL1000
      BWSLA2 = (BWSL4-BWSL3)*DLINC+BWSL3                                        BWSL1010
      WETLEN(K) = ((BWSLA2-BWSLA1)*DINC+BWSLA1)*0.08333                         BWSL1020
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    3 CONTINUE                                                                BWSL1030
C                                                                             BWSL1040
      N = NSTA(3)-1                                                           BWSL1050
C                                                                             BWSL1060
      DO 10 J=1,N                                                             BWSL1070
      WETLAV = (WETLEN(J+1)+WETLEN(J))*0.5                                    BWSL1080
      IF (WETLAV.LE.0.001) GO TO 8                                            BWSL1090
      DPFTAV = (DPFT(J+1)+DPFT(J))*0.5                                        BWSL1100
      ELSKIA = (ELSKI(J+1)+ELSKI(J))*0.5                                      BWSL1110
      ELSKDA = (ELSKID(J+1)+ELSKID(J))*0.04166                                BWSL1120
      SEALHT = HINGHT-ELSKDA                                                  BWSL1130
      DIFF = 2.0*CENCAB-(SEALHT+0.5)                                          BWSL1140
      IF (DIFF.GT.0.5) DIFF=0.5                                               BWSL1150
      ARM1B(J) = X1+WETLAV*0.5                                                BWSL1160
      ARM2B(J) = ZS-ELSKIA+DPFTAV*0.5                                         BWSL1170
      IF (DIFF.GE.0.25) GO TO 4                                               BWSL1180
      DFBS(J) = -DELP*DELYBS*WETLAV                                           BWSL1190
      GO TO 7                                                                 BWSL1200
    4 FORLEN = XBF-WETLAV                                                     BWSL1210
      IF (FORLEN.EQ.0.0) GO TO 5                                              BWSL1220
      ARGW = (HINGHT-ELSKIA)/FORLEN                                           BWSL1230
      IF (ARGW.GT.1.0) ARGW=1.0                                               BWSL1240
      ANGW = ARSIN(ARGW)                                                      BWSL1250
      FORCOS = COS(ANGW)                                                      BWSL1260
      GO TO 6                                                                 BWSL1270
    5 FORCOS = 0.0                                                            BWSL1280
    6 DFBS(J) = -DELP*DELYBS*WETLAV-DELP*FORLEN*DELYBS*FORCOS*((FORLEN*0BWSL1290
     1.5*FORCOS)/(FORLEN*FORCOS+WETLAV/2.0))*((DIFF-0.25)*4.0)                BWSL1300
    7 ARG = 0.5*RHO*U*U*WETLAV*DELYBS                                         BWSL1310
      RESKI = U*WETLAV/ENU                                                    BWSL1320
      CDTSKI = 0.427/(ALOG10(RESKI)-0.407)**2.64                              BWSL1330
      TSKIB(J) = -ARG*CDTSKI                                                  BWSL1340
      GO TO 9                                                                 BWSL1350
    8 DFBS(J) = 0.0                                                           BWSL1360
      TSKIB(J) = 0.0                                                          BWSL1370
    9 CONTINUE                                                                BWSL1380
      FX = FX+TSKIB(J)                                                        BWSL1390
      FZ = FZ+DFBS(J)                                                         BWSL1400
      FK = FK+DFBS(J)*YAVGB(J)                                                BWSL1410
      FM = FM-DFBS(J)*ARM1B(J)+TSKIB(J)*ARM2B(J)                              BWSL1420
      FN = FN-TSKIB(J)*YAVGB(J)                                               BWSL1430
      ALBS = ALBS+(GAP(J)+GAP(J+1))*DELYBS*0.5                                BWSL1440
   10 CONTINUE                                                                BWSL1450
C                                                                             BWSL1460
      ALBS = ALBS+BLEAK                                                       BWSL1470
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                       BWSL1480
      QL = CFBS*ALBS*SQFAC*SIGN(1.,PBAR)                                      BWSL1490
      IF (IBCWSL.NE.ON) RETURN                                                BWSL1500
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      WRITE (6,11) GAP,WETLEN,FX,FY,FZ,FK,FM,FN                          BWSL1510
C                                                                        BWSL1520
C                                                                        BWSL1530
      RETURN                                                             BWSL1540
C                                                                        BWSL1550
   11 FORMAT (//10X,8HBOW SEAL/26H GAP (FT.) (PORT TO STBD.)/11F10.5/28HBWSL1560
     1 WETLEN(FT.) (PORT TO STBD.)/11F10.5/10X,23HBOWSL FX,FY,FZ,FK,FM,FBWSL1570
     2N/6E15.4)                                                          BWSL1580
      END                                                                BWSL1590

      SUBROUTINE COLFIL                                                  CFL    10
C                                                                        CFL    20
      COMMON /AXIS/ NXYS(26)                                             CFL    30
      COMMON /COLUMN/ IVERT,ILATRL                                       CFL    40
      COMMON /CURVE/ NCURV(10)                                           CFL    50
      COMMON /EQNCO/ NEQS,TOL(20),JQQ                                    CFL    60
      COMMON /GRAF/ NGRAF,NDRW                                           CFL    70
      COMMON /HEADG/ TICRD(6)                                            CFL    80
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   CFL    90
      COMMON /STEP/ STEP2                                                CFL   100
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                     CFL   110
      REAL *8TICRD                                                       CFL   120
      REAL LABEL                                                         CFL   130
      REAL LAB(4)/'','1','2','3'/                                        CFL   140
      REAL *8NAMES(52)/'TIME','','WAVEHEI','GHT','ZDISPLA','CEMENT','PITCFL   150
     1CHAN','GLE','PLENUMP','RESSURE','BOWACCE','LERATION','C.G.ACCE','LCFL   160
     2ERATION','FANPOWE','R(IDEAL)','ROLLANG','LE','YAWANGL','E','LATACCCFL   170
     3E','LERATION','SPEEDTH','RUWATER','TURNRAD','IUS','PLENUMV','OLUMECFL   180
     4','XDISPLA','CEMENT','YDISPLA','CEMENT','AIRFLOW','IN','AIRFLOW','CFL   190
     5CUT','NETFORC','EXDIR','WAVEFOR','CEXDIR','THRUSTS','TARBOARD','THCFL   200
     6RUSTP','ORTSIDE','PITCH','RATE','ROLL','RATE','YAW','RATE','RUDDERCFL   210
     7A','NGLE'/                                                         CFL   220
      REAL *8TITLE(12)                                                   CFL   230
      REAL *8LINE2(2)/'PLOTIS','VERSUS'/                                 CFL   240
      REAL *8NAMEX(2),NAMEY(2),INAME(16)                                 CFL   250
      EQUIVALENCE (TITLE(1),TICRD(1)), (TITLE(2),TICRD(2)), (TITLE(3),TICFL   260
     1CRD(3)), (TITLE(4),TICRD(4)), (TITLE(5),TICRD(5)), (TITLE(6),TICRDCFL   270
     2(6))                                                               CFL   280
      DIMENSION PVQQ(26), XOUT(900), YOUT(900), AFILE(8)                 CFL   290
      DIMENSION THSTS(1), THSTP(1)                                       CFL   300
      EQUIVALENCE (PVQQ(1),TIME), (PVQQ(2),ETA), (PVQQ(3),Z), (PVQQ(4),TCFL   310
     1HETA), (PVQQ(5),PB), (PVQQ(6),BOWACC), (PVQQ(7),ACC), (PVQQ(8),FANCFL   320
     2PWR), (PVQQ(9),PHI), (PVQQ(10),BETAS), (PVQQ(11),ACCLAT), (PVQQ(12CFL   330
     3),U), (PVQQ(13),TRADUS), (PVQQ(14),VOLP), (PVQQ(15),X), (PVQQ(16),CFL   340
     4Y), (PVQQ(17),QIN), (PVQQ(18),QOUT), (PVQQ(19),GFXXX), (PVQQ(20),FCFL   350
     5XPWAV), (PVQQ(21),THSTS(1)), (PVQQ(22),THSTP(1)), (PVQQ(23),QDEG),CFL   360
     6 (PVQQ(24),PDEG), (PVQQ(25),RDEG), (PVQQ(26),DELRS)                CFL   370
C                                                                        CFL   380
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      IF (JQQ.NE.2) GO TO 1                                                    CFL  390
      WRITE (6,23) STEP2                                                       CFL  400
    1 END FILE 1                                                               CFL  410
      REWIND 1                                                                 CFL  420
      TITLE(7) = LINE2(1)                                                      CFL  430
      TITLE(10) = LINE2(2)                                                     CFL  440
      IF (NGRAF.EQ.0) GO TO 7                                                  CFL  450
      J = 1                                                                    CFL  460
      NGF = NGRAF                                                              CFL  470
      INDEX = NGRAF*2                                                          CFL  480
C                                                                              CFL  490
      DO 6 I=1,INDEX,2                                                         CFL  500
      INDX = NXYS(I)                                                           CFL  510
      INDY = NXYS(I+1)                                                         CFL  520
      IQ = 0                                                                   CFL  530
    2 READ (1,END = 8) TIME,ETA,Z,THETA,PB,BOWACC,ACC,FANPWR,PHI,BETAS,ACFL  540
     1CCLAT,U,TRADUS,VOLP,X,Y,QIN,QOUT,GFXXX,FXPWAV,THSTS(1),THSTP(1),QDCFL  550
     2FG,PDEG,RDEG,DELRS                                                       CFL  560
      IF (IQ.GE.900) GO TO 3                                                   CFL  570
      IQ = IQ+1                                                                CFL  580
      XOUT(IQ) = PVQQ(INDX)                                                    CFL  590
      YOUT(IQ) = PVQQ(INDY)                                                    CFL  600
      GO TO 2                                                                  CFL  610
    3 REWIND 1                                                                 CFL  620
      INX = INDX*2                                                             CFL  630
      INY = INDY*2                                                             CFL  640
      NAMEX(1) = NAMES(INX-1)                                                  CFL  650
      NAMEX(2) = NAMES(INX)                                                    CFL  660
      NAMEY(1) = NAMES(INY-1)                                                  CFL  670
      NAMEY(2) = NAMES(INY)                                                    CFL  680
      IF (NDRW.EQ.1) GO TO 4                                                   CFL  690
C                                                                              CFL  700
      CALL PLOTP (XOUT,YOUT,-IQ,0)                                             CFL  710
C                                                                              CFL  720
      WRITE (6,24) NAMEX,NAMEY                                                 CFL  730
      GO TO 6                                                                  CFL  740
    4 TITLE(8) = NAMEY(1)                                                      CFL  750
      TITLE(9) = NAMEY(2)                                                      CFL  760
      TITLE(11) = NAMEX(1)                                                     CFL  770
      TITLE(12) = NAMEX(2)                                                     CFL  780
      NCUR = NCURV(J)                                                          CFL  790
      IF (NCUR.NE.0) GO TO 5                                                   CFL  800
      LABEL = LAB(1)                                                           CFL  810
C                                                                              CFL  820
      CALL DRAW (IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)CFL  830
C                                                                              CFL  840
      J = J+1                                                                  CFL  850
      GO TO 6                                                                  CFL  860
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    5 WRITE (2) IQ,NCUR,NGF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(L),L=1CFL  870
     1,IQ)                                                                CFL  880
      NGF = NGF-1                                                         CFL  890
    6 CONTINUE                                                            CFL  900
C                                                                         CFL  910
      IF ((NGF.EQ.0).AND.(NCUR.EQ.3)) GO TO 10                            CFL  920
    7 IF (IVERT.NE.1) GO TO 16                                            CFL  930
      WRITE (6,25)                                                        CFL  940
      K = 0                                                               CFL  950
C                                                                         CFL  960
      DO 8 I=1,8                                                          CFL  970
      IF (ISUM1(I).NE.0) K=K+1                                            CFL  980
    8 CONTINUE                                                            CFL  990
C                                                                         CFL 1000
      NUM1 = K                                                            CFL 1010
      IF (K.EQ.0) GO TO 16                                                CFL 1020
      N = K*2                                                             CFL 1030
      J = 1                                                               CFL 1040
C                                                                         CFL 1050
      DO 9 I=1,NUM1                                                       CFL 1060
      IDEX = ISUM1(I)*2                                                   CFL 1070
      INAME(J) = NAMES(IDEX-1)                                            CFL 1080
      INAME(J+1) = NAMES(IDEX)                                            CFL 1090
      J = J+2                                                             CFL 1100
    9 CONTINUE                                                            CFL 1110
C                                                                         CFL 1120
      WRITE (6,26) (INAME(I),I=1,N)                                       CFL 1130
      GO TO 14                                                            CFL 1140
   10 END FILE 2                                                          CFL 1150
      REWIND 2                                                            CFL 1160
      NGF = NGRAF                                                         CFL 1170
      J = 1                                                               CFL 1180
   11 READ (2,END = 38) IQ,NCUR,NGRAF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YCFL 1190
     1OUT(L),L=1,IQ)                                                      CFL 1200
      IF ((NGF.EQ.NGRAF).AND.(NCUR.EQ.J)) GO TO 12                        CFL 1210
      GO TO 11                                                            CFL 1220
   12 LABEL = LAB(J+1)                                                    CFL 1230
C                                                                         CFL 1240
      CALL DRAW (IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)CFL 1250
C                                                                         CFL 1260
      REWIND 2                                                            CFL 1270
      J = J+1                                                             CFL 1280
      IF (J.EQ.4) GO TO 13                                                CFL 1290
      GO TO 11                                                            CFL 1300
   13 NGF = NGF-1                                                         CFL 1310
      IF (NGF.EQ.0) GO TO 7                                               CFL 1320
      J = 1                                                               CFL 1330
      GO TO 11                                                            CFL 1340
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   14 READ (1,END = 13) (PVQQ(I),I=1,26)                                    CFL 1350
C                                                                           CFL 1360
      DO 15 I=1,NUM1                                                        CFL 1370
      J = ISUM1(I)                                                          CFL 1380
   15 AFILE(I) = PVQQ(J)                                                    CFL 1390
C                                                                           CFL 1400
      WRITE (6,27) (AFILE(I),I=1,NUM1)                                      CFL 1410
      GO TO 14                                                              CFL 1420
      REWIND 1                                                              CFL 1430
   16 IF (ILATRL.NE.1) GO TO 22                                             CFL 1440
      WRITE (6,28)                                                          CFL 1450
      K = 0                                                                 CFL 1460
C                                                                           CFL 1470
      DO 17 I=1,8                                                           CFL 1480
      IF (ISUM2(I).NE.0) K=K+1                                              CFL 1490
   17 CONTINUE                                                              CFL 1500
C                                                                           CFL 1510
      NUM2 = K                                                              CFL 1520
      IF (K.EQ.0) GO TO 21                                                  CFL 1530
      N = K*2                                                               CFL 1540
      J = 1                                                                 CFL 1550
C                                                                           CFL 1560
      DO 18 I=1,NUM2                                                        CFL 1570
      IDEX = ISUM2(I)*2                                                     CFL 1580
      INAME(J) = NAMES(IDEX-1)                                              CFL 1590
      INAME(J+1) = NAMES(IDEX)                                              CFL 1600
      J = J+2                                                               CFL 1610
   18 CONTINUE                                                              CFL 1620
C                                                                           CFL 1630
      WRITE (6,26) (INAME(I),I=1,N)                                         CFL 1640
   19 READ (1,END = 16) (PVQQ(I),I=1,26)                                    CFL 1650
C                                                                           CFL 1660
      DO 20 I=1,NUM2                                                        CFL 1670
      J = ISUM2(I)                                                          CFL 1680
   20 AFILE(I) = PVQQ(J)                                                    CFL 1690
C                                                                           CFL 1700
      WRITE (6,27) (AFILE(I),I=1,NUM2)                                      CFL 1710
      GO TO 19                                                              CFL 1720
   21 REWIND 1                                                              CFL 1730
   22 RETURN                                                                CFL 1740
C                                                                           CFL 1750
   23 FORMAT ('0',4X,'THIS RUN USED VARIABLE STEP SIZE',/,'0',4X,'THE MI    CFL 1760
     1NIMUM STEPSIZE RECORDED DURING THE RUN WAS',2X,E30.5)                 CFL 1770
   24 FORMAT (' ',20X,2A8,' IS THE INDEPENDENT VARIABLE AND ',2A8,' THE     CFL 1780
     1DEPENDENT VARIABLE')                                                  CFL 1790
   25 FORMAT ('0',50X,'***SUMMARY ONE***',/,'0')                            CFL 1800
   26 FORMAT ('0',16A8)                                                     CFL 1810
   27 FORMAT ('0',8(3X,F10.2,3X))                                           CFL 1820
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   28 FORMAT ('0',50X,'***SUMMARY TWO***',/,'0')                          CFL 1830
      END                                                                 CFL 1840

      SUBROUTINE FAN                                                      FAN   10
C                                                                         FAN   20
      INTEGER ON                                                          FAN   30
      COMMON /AIR/ PINF,RHOINF,GAM                                        FAN   40
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,ENFAN   50
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2FAN   60
     25),TMEB(25),DELB(25),NB,TMES(25),DELS(25),NS                        FAN   70
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7    FAN   80
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IFAN   90
     1RUD,IPROP,IAEROD,IRHS                                               FAN  100
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVFAN  110
     1GB(10)                                                              FAN  120
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVFAN  130
     1GS(10)                                                              FAN  140
      COMMON /VARBLE/ VAL(40)                                             FAN  150
      DIMENSION QB(1), QM(1), QS(1), PBOW(1), PM(1), PS(1), HP(8)         FAN  160
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAFAN  170
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAFAN  180
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)FAN  190
     3, (VAL(24),PB)                                                      FAN  200
      EQUIVALENCE (VAL(18),FANPWR)                                        FAN  210
      EQUIVALENCE (QBFAN(1),QB(1)), (QMFAN(1),QM(1)), (QSFAN(1),QS(1)),   FAN  220
     1(PBFAN(1),PBOW(1)), (PMFAN(1),PM(1)), (PSFAN(1),PS(1))              FAN  230
      DATA HP/2.9,2.3,1.95,1.77,1.85,2.05,1.93,1.62/                      FAN  240
C                                                                         FAN  250
      BRAT = 8000/BRPM                                                    FAN  260
      EMRAT = 8000/EMRPM                                                  FAN  270
      SRAT = 8000/SRPM                                                    FAN  280
      TL = VAL(1)                                                         FAN  290
      IF (NB.EQ.0.0) GO TO 1                                              FAN  300
      DPBS = FG1(TL,NB,TMEB,DELB,ILB)                                     FAN  310
      PBS = PB+DPBS                                                       FAN  320
    1 IF (NS.EQ.0.0) GO TO 2                                              FAN  330
      DPSS = FG1(TL,NS,TMES,DELS,ILS)                                     FAN  340
      PSS = PB+DPSS                                                       FAN  350
    2 CONTINUE                                                            FAN  360
      PB1 = PBS-PINF                                                      FAN  370
      PB2 = PB-PINF                                                       FAN  380
      PB3 = PSS-PINF                                                      FAN  390
      PBARB = PB1*BRAT*BRAT                                               FAN  400
      PBARM = PB2*EMRAT*EMRAT                                             FAN  410
      PBARS = PB3*SRAT*SRAT                                               FAN  420
      QBOW = ENBFAN*FG1(PBARB,NPTSB,PBOW,QB,IB)/BRAT                      FAN  430
      QMAIN = ENMFAN*FG1(PBARM,NPTSM,PM,QM,IM)/EMRAT                      FAN  440
      QSTN = ENSFAN*FG1(PBARS,NPTSS,PS,QS,IS)/SRAT                        FAN  450
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      QIN = QBOW+QMAIN+QSTN                                                    FAN   460
      MB1 = (QBOW/ENBFAN+5.0)/5.0                                              FAN   470
      MB2 = MB1+1                                                              FAN   480
      MB3 = MB2+1                                                              FAN   490
      BINC = ((QBOW/ENBFAN+5.0)-MB1*5.0)/5.0                                   FAN   500
      BFANHP = ((HP(MB3)-HP(MB2))*BINC+HP(MB2))*ENBFAN*(1./BRAT)**3            FAN   510
      MS1 = (QSTN/ENSFAN+5.0)/5.0                                              FAN   520
      MS2 = MS1+1                                                              FAN   530
      MS3 = MS2+1                                                              FAN   540
      STINC = ((QSTN/ENSFAN+5.0)-MS1*5.0)/5.0                                  FAN   550
      SFANHP = ((HP(MS3)-HP(MS2))*STINC+HP(MS2))*ENSFAN*(1./SRAT)**3           FAN   560
      MM1 = (QMAIN/ENMFAN+5.0)/5.0                                             FAN   570
      MM2 = MM1+1                                                              FAN   580
      MM3 = MM2+1                                                              FAN   590
      PLINC = ((QMAIN/ENMFAN+5.0)-MM1*5.0)/5.0                                 FAN   600
      PFANHP = ((HP(MM3)-HP(MM2))*PLINC+HP(MM2))*ENMFAN*(1./EMRAT)**3          FAN   610
      RELPWR = PFANHP+BFANHP+SFANHP                                            FAN   620
      FANPWR = (QBOW*PB1+QMAIN*PB2+QSTN*PB3)/550.                              FAN   630
      FANEFF = FANPWR/RELPWR                                                   FAN   640
      IF (IRHS.NE.ON) RETURN                                                   FAN   650
      WRITE (6,3) QBOW,QMAIN,QSTN,PBARB,PBARM,PBARS,RELPWR,FANPWR,FANEFF       FAN   660
C                                                                              FAN   670
C                                                                              FAN   680
      RETURN                                                                   FAN   690
C                                                                              FAN   700
    3 FORMAT (//4H FAN/32H Q - BOW,MAIN,STERN (CU FT /SEC)3F12.1/28H DEL       FAN   710
     1P - BOW,MAIN,STERN (PSF)3F11.2/60H ACTUAL FAN POWER REQUIRED(HP),        FAN   720
     2IDEAL FAN POWER, EFFICIENCY 3F12.4)                                      FAN   730
      END                                                                      FAN   740

      FUNCTION FG1 (X,N,XT,YT,IX)                                              FG1    10
C                                                                              FG1    20
      DIMENSION XT(1), YT(1)                                                   FG1    30
C                                                                              FG1    40
      IF (IX.LT.1) IX = 1                                                      FG1    50
      IF (IX.GT.N-1) IX = N-1                                                  FG1    60
      I = SIGN(1.0,X-XT(IX))                                                   FG1    70
    1 IF (IX.LT.1.OR.IX.GE.N) GO TO 3                                          FG1    80
      IF (XT(IX).GT.X.OR.X.GT.XT(IX+1)) GO TO 2                                FG1    90
      C = (X-XT(IX))/(XT(IX+1)-XT(IX))                                         FG1   100
      GO TO 4                                                                  FG1   110
    2 IX = IX+I                                                                FG1   120
      GO TO 1                                                                  FG1   130
    3 C = IX/N                                                                 FG1   140
      IX = IX-I                                                                FG1   150
    4 FG1 = YT(IX)+C*(YT(IX+1)-YT(IX))                                         FG1   160
      RETURN                                                                   FG1   170
      END                                                                      FG1   180
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      SUBROUTINE INCON (TIME)                                                    INCN   10
C                                                                                INCN   20
      REAL *8TICRD                                                               INCN   30
      INTEGER ON                                                                 INCN   40
      COMMON /AIR/ PINF,RHOINF,GAM                                               INCN   50
      COMMON /AXIS/ NXYS(26)                                                     INCN   60
      COMMON /ATRIX/ AMASSI,AIYYI,DIXX,DIXZ,DIZZ                                 INCN   70
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY          INCN   80
      COMMON /COLUMN/ IVERT,ILATRL                                               INCN   90
      COMMON /CONST/ PI,RAD,UO                                                   INCN  100
      COMMON /CNTRL/ CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUI         INCN  110
     1L,THEQL,ACBASE                                                             INCN  120
      COMMON /CURVE/ NCURV(10)                                                   INCN  130
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIP         INCN  140
     1(25),TIS(25)                                                               INCN  150
      COMMON /EQNCO/ NEQS,TOL(20),JQQ                                            INCN  160
      COMMON /FAIR/ RHOA,XLAERO                                                  INCN  170
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN         INCN  180
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2         INCN  190
     25),TMEB(25),DELB(25),NB,TMES(25),DETS(25),NS                               INCN  200
      COMMON /FROUDE/ FN,FNCRIT                                                  INCN  210
      COMMON /GBOW/ XBOW                                                         INCN  220
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,         INCN  230
     110),XCP,ZCP                                                               INCN  240
      COMMON /GEOMSW/ XAVG(10),DS                                                INCN  250
      COMMON /GRAF/ NGRAF,NDRW                                                   INCN  260
      COMMON /HEADG/ TICRD(6)                                                    INCN  270
      COMMON /PWAVE/ FNCON,PWVCON                                                INCN  280
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS                                      INCN  290
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM         INCN  300
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                                  INCN  310
      COMMON /MATRIX/ A(6,6)                                                     INCN  320
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA                                     INCN  330
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,CMM                      INCN  340
      COMMON /PLVCQQ/ NVI,NVD,NLI,NLD                                            INCN  350
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                              INCN  360
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I         INCN  370
     1RUD,IPROP,IAEROD,IRHS                                                      INCN  380
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7           INCN  390
      COMMON /ROLL/ PHIMAX,TROLL                                                 INCN  400
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,R         INCN  410
     1CLB,RTC,RUDANG,TIR(25)                                                     INCN  420
      COMMON /RISER/ AMPTC                                                       INCN  430
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAV         INCN  440
     1GB(10),CENCAB                                                              INCN  450
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV         INCN  460
     1GS(10)                                                                     INCN  470
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      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSINCN 480
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC          INCN 490
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                     INCN 500
      COMMON /STABLE/ S(4),ISTAB                                         INCN 510
      COMMON /STSLR/ CPHI,CPHID                                          INCN 520
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                     INCN 530
      COMMON /VALOLD/ YOLD(20)                                           INCN 540
      COMMON /VARBLE/ VAL(40)                                            INCN 550
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYINCN 560
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBINCN 570
     2BAR                                                               INCN 580
      COMMON /WAVEF/ WAVLEN(20),OMEGAE(20),WAVSLP(20),ENCPER(20)         INCN 590
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACINCN 600
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5INCN 610
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),AINCN 620
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,INCN 630
     45,7),AS0(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX          INCN 640
      DIMENSION ZZZ(14050)                                               INCN 650
      EQUIVALENCE (ZZZ,NAL)                                              INCN 660
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6INCN 670
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(INCN 680
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB),INCN 690
     3 (VAL(12),VOL)                                                    INCN 700
      DIMENSION TEMP(7), XMO(10)                                         INCN 710
      DIMENSION TITLC(20)                                                INCN 720
      DATA BEAM,BETAD,DELO,DELPI,DLRDO,DSO,ISYS,RMAXO,RONO,RRATO,RREVO,TINCN 730
     1HETO,THSSI,TPRINO,UO,VXO,VZO,XBSI,XCPO,XLTOT,XPO,XRO,XSSI,YPO,ZPO,INCN 740
     2ZRO,ZSSI/6*0.0,0,20*0.0/                                          INCN 750
C                                                                       INCN 760
CC    INITIAL CONDITIONS WITH WATSLP                                    INCN 770
CC                                                                      INCN 780
C                                                                       INCN 790
      DO 1 I=1,8                                                        INCN 800
      ISUM1(I) = 0                                                      INCN 810
    1 ISUM2(I) = 0                                                      INCN 820
C                                                                       INCN 830
      PINF = 2116.                                                      INCN 840
      RHOINF = .002378                                                  INCN 850
      GAM = 1.4                                                         INCN 860
      GO TO 3                                                           INCN 870
    2 READ (5,98) NGRAF,NDRW                                            INCN 880
      READ (5,99) NXYS                                                  INCN 890
      READ (5,100) TICRD                                                INCN 900
    3 READ (5,107) ISYSL,IOPT,(TEMP(I),I=1,7)                           INCN 910
      IF (ISYSL.EQ.ISYS.AND.ISYSL.EQ.13) GO TO 97                       INCN 920
      ISYS = ISYSL                                                      INCN 930
      IF ((ISYS.LE.0).OR.(ISYS.GT.22)) GO TO 97                         INCN 940
      GO TO (4,14,23,24,27,28,31,34,37,41,42,52,53,74,75,82,89,92,93,6,7INCN 950
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     1,2), ISYS                                                                    INCN 960
C                                                                                  INCN 970
CC     PROGRAM CONTROL PARAMETERS                                                  INCN 980
C                                                                                  INCN 990
    4 CONTINUE                                                                     INCN1000
      GO TO (5,8,9,10,11,12), IOPT                                                 INCN1010
    5 CONTINUE                                                                     INCN1020
      STIME = TEMP(1)                                                              INCN1030
      FTIME = TEMP(2)                                                              INCN1040
      DELO = TEMP(3)                                                               INCN1050
      DELPNT = TEMP(4)                                                             INCN1060
      TPRINO = TEMP(5)                                                             INCN1070
      IF (TPRINO.LT.STIME+DELPNT) TPRINO=STIME+DELPNT                              INCN1080
      IF (DELO.GT.DELPNT) DELO=DELPNT                                              INCN1090
      IF (DELO.EQ.0.0) GO TO 13                                                    INCN1100
      GO TO 3                                                                      INCN1110
    6 READ (5,101) NCURV                                                           INCN1120
      GO TO 3                                                                      INCN1130
    7 READ (5,102) ISUM1                                                           INCN1140
      READ (5,102) ISUM2                                                           INCN1150
      GO TO 3                                                                      INCN1160
    8 READ (5,108) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,IP         INCN1170
     1ROP,IAEROD,IRHS                                                              INCN1180
      GO TO 3                                                                      INCN1190
    9 READ (5,111) NEQS,JQQ,(TOL(J),J=1,NEQS)                                      INCN1200
      GO TO 3                                                                      INCN1210
   10 READ (5,108) IVERT,ILATRL,NVD,NVI,NLD,NLI                                    INCN1220
      GO TO 3                                                                      INCN1230
   11 CONTINUE                                                                     INCN1240
      I3DOF = TEMP(1)                                                              INCN1250
      ISRGE = TEMP(2)                                                              INCN1260
      ITRIM = TEMP(3)                                                              INCN1270
      IDIA = TEMP(4)                                                               INCN1280
      GO TO 3                                                                      INCN1290
   12 CONTINUE                                                                     INCN1300
      PROMO1 = TEMP(1)                                                             INCN1310
      PROMO2 = TEMP(2)                                                             INCN1320
      PROMO3 = TEMP(3)                                                             INCN1330
      PROMO4 = TEMP(4)                                                             INCN1340
      PROMO5 = TEMP(5)                                                             INCN1350
      PROMO6 = TEMP(6)                                                             INCN1360
      PROMO7 = TEMP(7)                                                             INCN1370
      GO TO 3                                                                      INCN1380
   13 WRITE (6,110)                                                                INCN1390
      STOP                                                                         INCN1400
C                                                                                  INCN1410
CC     MASS DISTRIBUTION                                                           INCN1420
C                                                                                  INCN1430
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   14 G = 32.17                                                                  INCN1440
      RHO = 1.99                                                                 INCN1450
      HRHO = RHO*.5                                                              INCN1460
      GO TO (15,17,22), IOPT                                                     INCN1470
   15 IMM = 0                                                                    INCN1480
      WEIGHT = TEMP(1)                                                           INCN1490
      AM = WEIGHT/G                                                              INCN1500
      XS = TEMP(2)                                                               INCN1510
      ZS = TEMP(3)                                                               INCN1520
      AIXX = TEMP(4)                                                             INCN1530
      AIYY = TEMP(5)                                                             INCN1540
      AIZZ = TEMP(6)                                                             INCN1550
      AIXZ = TEMP(7)                                                             INCN1560
C                                                                                INCN1570
CC    INERTIA MATRIX OPERATIONS                                                  INCN1580
C                                                                                INCN1590
   16 AMASSI = 1.0/AM                                                            INCN1600
      D = 1.0/(AIXX*AIZZ-AIXZ*AIXZ)                                              INCN1610
      DIXX = AIXX*D                                                              INCN1620
      DIXZ = AIXZ*D                                                              INCN1630
      DIZZ = AIZZ*D                                                              INCN1640
      AIYYI = 1.0/AIYY                                                           INCN1650
      GO TO 3                                                                    INCN1660
C                                                                                INCN1670
CC    READ WEIGHT DISTRIBUTION - ASSUME TRANSVERSE (PORT/STBD) SYMMETRY          INCN1680
C        X INPUT DIST. FWD. OF (SIDEWALL) TRANSOM                                INCN1690
C        Y INPUT DIST. TO STARBOARD                                              INCN1700
C        Z INPUT DIST. UP FROM KEEL-LINE                                         INCN1710
C                                                                                INCN1720
   17 I = 1                                                                      INCN1730
   18 READ (5,109) AMI(I),XI(I),YI(I),ZI(I)                                      INCN1740
      IF (AMI(I).LT.0.0) GO TO 19                                                INCN1750
      I = I+1                                                                    INCN1760
      IF (I.GT.201) GO TO 97                                                     INCN1770
      GO TO 18                                                                   INCN1780
   19 NMASS = I-1                                                                INCN1790
      SUM = 0.0                                                                  INCN1800
      SUX = 0.0                                                                  INCN1810
      SUZ = 0.0                                                                  INCN1820
C                                                                                INCN1830
      DO 20 I=1,NMASS                                                            INCN1840
      AMI(I) = AMI(I)/G                                                          INCN1850
      SUM = SUM+AMI(I)                                                           INCN1860
      SUX = SUX+AMI(I)*XI(I)                                                     INCN1870
   20 SUZ = SUZ+AMI(I)*ZI(I)                                                     INCN1880
C                                                                                INCN1890
      AM = SUM*2.0                                                               INCN1900
      WEIGHT = AM*G                                                              INCN1910
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      ZS = SUZ/SUM                                                      INCN1920
      XS = SUX/SUM                                                      INCN1930
      SUM = 0.0                                                         INCN1940
      SUX = 0.0                                                         INCN1950
      SUY = 0.0                                                         INCN1960
      SUZ = 0.0                                                         INCN1970
C                                                                       INCN1980
      DO 21 I=1,NMASS                                                   INCN1990
      XI(I) = XI(I)-XS                                                  INCN2000
      ZI(I) = -ZI(I)+ZS                                                 INCN2010
      AMK = AMI(I)*2.0                                                  INCN2020
      SUX = SUX+AMK*XI(I)*XI(I)                                         INCN2030
      SUY = SUY+AMK*YI(I)*YI(I)                                         INCN2040
      SUZ = SUZ+AMK*ZI(I)*ZI(I)                                         INCN2050
   21 SUM = SUM+AMK*XI(I)*ZI(I)                                         INCN2060
C                                                                       INCN2070
      AIXX = SUY+SUZ                                                    INCN2080
      AIYY = SUX+SUZ                                                    INCN2090
      AIZZ = SUX+SUY                                                    INCN2100
      AIXZ = SUM                                                        INCN2110
      GO TO 16                                                          INCN2120
   22 GO TO 3                                                           INCN2130
C                                                                       INCN2140
C     XX AND YY TABLES                                                  INCN2150
C                                                                       INCN2160
   23 CONTINUE                                                          INCN2170
      NSTA(1) = TEMP(1)                                                 INCN2180
      NSTA(2) = TEMP(2)                                                 INCN2190
      NSTA(3) = TEMP(3)                                                 INCN2200
      NSTA(4) = TEMP(4)                                                 INCN2210
      XLTOT = TEMP(5)                                                   INCN2220
      GO TO 3                                                           INCN2230
C                                                                       INCN2240
C     SIDEWALL (INCLUDING APPENDAGES)                                   INCN2250
C                                                                       INCN2260
   24 CONTINUE                                                          INCN2270
      GO TO (25,26), IOPT                                               INCN2280
   25 YSW = TEMP(1)                                                     INCN2290
      XLSW = TEMP(2)                                                    INCN2300
      CFSW = TEMP(3)                                                    INCN2310
      CDSW = TEMP(4)                                                    INCN2320
      AVBMSW = TEMP(5)                                                  INCN2330
      READ (10) ZZZ                                                     INCN2340
      REWIND 10                                                         INCN2350
      GO TO 3                                                           INCN2360
C                                                                       INCN2370
C     BLOCK 4 OPTION 2 REMOVED.       NO APENDAGES                      INCN2380
C                                                                       INCN2390
```

```
   26 CONTINUE                                                          INCN2400
      GO TO 3                                                           INCN2410
C                                                                       INCN2420
CC    STERNSEAL                                                         INCN2430
C                                                                       INCN2440
   27 CONTINUE                                                          INCN2450
      XSSI = TEMP(1)                                                    INCN2460
      ZSSI = TEMP(2)                                                    INCN2470
      ALEAK = TEMP(3)                                                   INCN2480
      CFSS = TEMP(4)                                                    INCN2490
      ELMAXS = TEMP(5)                                                  INCN2500
      DPSS = TEMP(6)                                                    INCN2510
      XLF = TEMP(7)                                                     INCN2520
      ARGA = ELMAXS/XLF                                                 INCN2530
      COSTH = ARGA                                                      INCN2540
      THSSI = ARCOS(ARGA)                                               INCN2550
      SINTH = SIN(THSSI)                                                INCN2560
      GO TO 3                                                           INCN2570
C                                                                       INCN2580
CC    BOWSEAL                                                           INCN2590
C                                                                       INCN2600
   28 GO TO (29,30), IOPT                                               INCN2610
   29 CONTINUE                                                          INCN2620
      XBSI = TEMP(1)                                                    INCN2630
      CFBS = TEMP(2)                                                    INCN2640
      DPBS = TEMP(3)                                                    INCN2650
      ZBSI = TEMP(4)                                                    INCN2660
      ELMAXB = TEMP(5)                                                  INCN2670
      XBF = TEMP(6)                                                     INCN2680
      BLEAK = TEMP(7)                                                   INCN2690
      GO TO 3                                                           INCN2700
   30 CENCAB = TEMP(1)                                                  INCN2710
      GO TO 3                                                           INCN2720
C                                                                       INCN2730
CC    PLENUM                                                            INCN2740
C                                                                       INCN2750
   31 CONTINUE                                                          INCN2760
      GO TO (32,33), IOPT                                               INCN2770
   32 CONTINUE                                                          INCN2780
      XLBW = TEMP(1)                                                    INCN2790
      XBBW = TEMP(2)                                                    INCN2800
      XPWV = TEMP(3)                                                    INCN2810
      WIDTH = TEMP(4)                                                   INCN2820
      XL = TEMP(5)                                                      INCN2830
      XCPO = TEMP(6)                                                    INCN2840
      BUBHGT = TEMP(7)                                                  INCN2850
      XLXPWV = XLBW-XPWV                                                INCN2860
      PWVHT = (XPWV*XPWV-XLXPWV*XLXPWV)*.5/XL                           INCN2870
```

```
      XPWVXS = XPWV-XS                                                  INCN2880
      ABW = XBBW*XLBW                                                   INCN2890
      AB = WIDTH*XL                                                     INCN2900
      VOLNOM = (ABW+AB)*BUBHGT*.5                                       INCN2910
      GO TO 3                                                           INCN2920
   33 CONTINUE                                                          INCN2930
      FNCRIT = TEMP(1)                                                  INCN2940
      GO TO 3                                                           INCN2950
C                                                                       INCN2960
CC    PROPULSION                                                        INCN2970
C                                                                       INCN2980
   34 CONTINUE                                                          INCN2990
      GO TO (35,36), IOPT                                               INCN3000
   35 CONTINUE                                                          INCN3010
      XPO = TEMP(1)                                                     INCN3020
      YPO = TEMP(2)                                                     INCN3030
      ZPO = TEMP(3)                                                     INCN3040
      GO TO 3                                                           INCN3050
C                                                                       INCN3060
CC BLOCK 8 OPTION 2 REMOVED. ENGINE OUT INPUT IN BLOCK 16               INCN3070
C                                                                       INCN3080
   36 CONTINUE                                                          INCN3090
      GO TO 3                                                           INCN3100
C                                                                       INCN3110
CC    RUDDER                                                            INCN3120
C                                                                       INCN3130
   37 CONTINUE                                                          INCN3140
      GO TO (38,39,40), IOPT                                            INCN3150
   38 XRO = TEMP(1)                                                     INCN3160
      YR = TEMP(2)                                                      INCN3170
      ZRO = TEMP(3)                                                     INCN3180
      RSPAN = TEMP(4)                                                   INCN3190
      RASPR = TEMP(5)                                                   INCN3200
      RAREA = TEMP(6)                                                   INCN3210
      RCLB = 2.*PI*RASPR/(RASPR+3.)                                     INCN3220
      RTC = TEMP(7)                                                     INCN3230
      GO TO 3                                                           INCN3240
C                                                                       INCN3250
CC    910 NOT USED                                                      INCN3260
C                                                                       INCN3270
   39 CONTINUE                                                          INCN3280
      GO TO 3                                                           INCN3290
   40 CONTINUE                                                          INCN3300
      GO TO 3                                                           INCN3310
C                                                                       INCN3320
CC    AERODYNAMICS                                                      INCN3330
C                                                                       INCN3340
   41 CONTINUE                                                          INCN3350
```

```
      XLAERO = TEMP(1)                                                  INCN3360
      BEAM = TEMP(2)                                                    INCN3370
      RHOA = .5*RHOINF*XLAERO*BEAM                                      INCN3380
      GO TO 3                                                           INCN3390
C                                                                       INCN3400
C     WAVES                                                             INCN3410
C                                                                       INCN3420
   42 CONTINUE                                                          INCN3430
      IWAVSW = ICPT                                                     INCN3440
      IF (IWAVSW.GT.4) GO TO 97                                         INCN3450
      NWAVE = TEMP(1)                                                   INCN3460
      IF (NWAVE.EQ.0) GO TO 3                                           INCN3470
      IF (NWAVE.GT.20) GO TO 97                                         INCN3480
      BETAD = TEMP(2)                                                   INCN3490
      BETA = BETAD/RAD                                                  INCN3500
      COSBET = COS(BETA)                                                INCN3510
      SINBET = SIN(BETA)                                                INCN3520
      TC = 1.0                                                          INCN3530
      GO TO (43,45,47,47), IWAVSW                                       INCN3540
C                                                                       INCN3550
   43 DO 44 I=1,NWAVE                                                   INCN3560
   44 READ (5,116) OMEGA(I),AW(I)                                       INCN3570
C                                                                       INCN3580
      GO TO 3                                                           INCN3590
C                                                                       INCN3600
   45 DO 46 I=1,NWAVE                                                   INCN3610
   46 READ (5,116) WAVLEN(I),AW(I)                                      INCN3620
C                                                                       INCN3630
      GO TO 3                                                           INCN3640
   47 SHTWV = TEMP(3)                                                   INCN3650
      G1G = 32.17                                                       INCN3660
      G2 = G1G*G1G                                                      INCN3670
      G4 = G2*G2                                                        INCN3680
      GO TO (3,3,48,49), IWAVSW                                         INCN3690
   48 CONTINUE                                                          INCN3700
      PERL = TEMP(4)                                                    INCN3710
      PERH = TEMP(5)                                                    INCN3720
      WWN = (2.0*3.141592)*(1.0/PERH)                                   INCN3730
      WWX = (2.0*3.141592)*(1.0/PERL)                                   INCN3740
      GO TO 50                                                          INCN3750
   49 CONTINUE                                                          INCN3760
      WWN = TEMP(4)                                                     INCN3770
      WWX = TEMP(5)                                                     INCN3780
   50 CONTINUE                                                          INCN3790
      UUU=SQRT(SHTWV*54.0)*1.6878                                       INCN3800
      UU4 = UUU*UUU*UUU*UUU                                             INCN3810
      CCC = (WWX/WWN)**(1./NWAVE)                                       INCN3820
      WWPO = WWN                                                        INCN3830
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```
C                                                                       INCN3840
      DO 51 I=1,NWAVE                                                   INCN3850
      WWPN = WWPO*CCC                                                   INCN3860
      WW = (WWPN+WWPO)*.5                                               INCN3870
      DDW = WWPN-WWPO                                                   INCN3880
      WWPO = WWPN                                                       INCN3890
      WW4 = WW*WW*WW*WW                                                 INCN3900
      WW5 = WW*WW4                                                      INCN3910
      SS = 0.0081*G2/(EXP(0.74*G4/(WW4*UU4))*WW5)                       INCN3920
      OMEGA(I) = WW                                                     INCN3930
      AW(I) = SQRT(2.*SS*DDW)                                           INCN3940
   51 CONTINUE                                                          INCN3950
C                                                                       INCN3960
      GO TO 3                                                           INCN3970
C                                                                       INCN3980
CCC   INITIAL CONDITIONS                                                INCN3990
C                                                                       INCN4000
   52 CONTINUE                                                          INCN4010
      UO = TEMP(1)                                                      INCN4020
      THETO = TEMP(2)                                                   INCN4030
      DSO = TEMP(3)                                                     INCN4040
      DELPI = TEMP(4)                                                   INCN4050
      DPHI = TEMP(5)                                                    INCN4060
      GO TO 3                                                           INCN4070
   53 CONTINUE                                                          INCN4080
C                                                                       INCN4090
CCC   INPUT COMPLETED. 1) PRINT ALL INPUT                               INCN4100
C                                                                       INCN4110
      WRITE (6,123) TITLC                                               INCN4120
      WRITE (6,124) STIME,FTIME,DELO,TPRINO,DELPNT                      INCN4130
      WRITE (6,125) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,I INCN4140
     1PROP,IAEROD,IRHS                                                  INCN4150
      WRITE (6,135) I3DOF,ISRGE,ITRIM,IDIA                              INCN4160
      WRITE (6,142) PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7    INCN4170
      WRITE (6,126) NEQS,(TOL(J),J=1,NEQS)                              INCN4180
      WRITE (6,113) WEIGHT,XS,ZS,AIXX,AIYY,AIZZ,AIXZ                    INCN4190
      WRITE (6,112) A,AIMAX                                             INCN4200
      WRITE (6,133) NSTA                                                INCN4210
      WRITE (6,114) YSW,XLSW,CFSW,CDSW,VANGLE,VSPAN,VCHORD,VXO,VY,VZO,AVINCN4220
     1BMSW,VTC                                                          INCN4230
      WRITE (6,115) NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB     INCN4240
      IF (IMM.GT.0) WRITE (6,121) (XMO(J),J=1,IMNX)                     INCN4250
      WRITE (6,119) IMM,IMNX,IMNY,IBMFIL,BTIME,IMT                      INCN4260
      IF (IMM.GT.0) WRITE (6,122) (YMI(J),J=1,IMNY)                     INCN4270
      WRITE (6,128) XLBW,XBBW                                           INCN4280
      WRITE (6,129) XL,WIDTH,XCPO,VOLNOM,BUBHGT                         INCN4290
      WRITE (6,134) DELPI                                               INCN4300
      WRITE (6,127) FNCRIT,XLTOT                                        INCN4310
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      WRITE (6,141) ENBFAN,BRPM,ENMFAN,EMRPM,ENSFAN,SRPM                    INCN4320
      WRITE (6,131) XRO,YR,ZRO,RONO,RMAXO,RRATO,RREVO,DLRDO,RSPAN,RASPR,    INCN4330
     1RAREA,RCLB,RTC                                                        INCN4340
      WRITE (6,130) XPO,YPO,ZPO                                             INCN4350
      WRITE (6,140) XLAERO,BEAM                                             INCN4360
      WRITE (6,139) XBSI,CFBS,DPBS,ELMAXB                                   INCN4370
      WRITE (6,138) XSSI,ZSSI,ALEAK,CFSS,ELMAXS,DPSS,XLF                    INCN4380
      WRITE (6,132) UO,THETO,DSO                                            INCN4390
C                                                                           INCN4400
CC                  AND 2) INITIALIZE VARIABLES FOR CALCS.                  INCN4410
CC                                                                          INCN4420
C                                                                           INCN4430
      DO 54 I=1,40                                                          INCN4440
   54 VAL(I) = 0.0                                                          INCN4450
C                                                                           INCN4460
      U = UO*1.6889                                                         INCN4470
      XSS = -(XS-XSSI)                                                      INCN4480
      ZSS = ZS-ZSSI                                                         INCN4490
      THETA = THETO/RAD                                                     INCN4500
      PHI = DPHI/RAD                                                        INCN4510
      THEQL = THETA                                                         INCN4520
      DS = DSO*.0833                                                        INCN4530
      Z = -ZS+DS                                                            INCN4540
      ZEQUIL = Z                                                            INCN4550
      PHIMAX = 0.                                                           INCN4560
      TROLL = 0.                                                            INCN4570
      IRDS = 0                                                              INCN4580
      TL = 0.0                                                              INCN4590
C                                                                           INCN4600
CC    WAVE PARAMETERS TABLE                                                 INCN4610
C                                                                           INCN4620
      IF (NWAVE.EQ.0) GO TO 61                                              INCN4630
      AMPTC = 1.30287                                                       INCN4640
      GO TO (55,57), IWAVSW                                                 INCN4650
C                                                                           INCN4660
   55 DO 56 I=1,NWAVE                                                       INCN4670
   56 WAVLEN(I) = 2.*PI*G/(OMEGA(I)*OMEGA(I))                               INCN4680
C                                                                           INCN4690
      GO TO 59                                                              INCN4700
C                                                                           INCN4710
   57 DO 58 I=1,NWAVE                                                       INCN4720
   58 OMEGA(I) = SQRT(2.*PI*G/WAVLEN(I))                                    INCN4730
C                                                                           INCN4740
   59 CONTINUE                                                              INCN4750
C                                                                           INCN4760
CC    CALCULATE INITIAL FREQUENCIES OF ENCOUNTER                            INCN4770
CC                                                                          INCN4780
C                                                                           INCN4790
```

```
      DO 60 I=1,NWAVE                                                    INCN4800
      WAVSLP(I) = 360.0*AW(I)/WAVLEN(I)                                  INCN4810
      CMEGAE(I) = 2.*PI*(SQRT(G*WAVLEN(I)/(2.*PI))-U*COSBET)/WAVLEN(I)   INCN4820
      ENCPER(I) = 2.0*PI/OMEGAE(I)                                       INCN4830
   60 CONTINUE                                                           INCN4840
C                                                                        INCN4850
      WRITE (6,117) NWAVE,BETAD,(OMEGA(I),OMEGAE(I),WAVLEN(I),AW(I),WAVSINCN4860
     1LP(I),ENCPER(I),I=1,NWAVE)                                         INCN4870
      GO TO 62                                                           INCN4880
   61 WRITE (6,118)                                                      INCN4890
   62 CONTINUE                                                           INCN4900
C                                                                        INCN4910
      DO 63 I=1,4                                                        INCN4920
C                                                                        INCN4930
      DO 63 N=1,11                                                       INCN4940
   63 ETA(I,N) = 0.0                                                     INCN4950
C                                                                        INCN4960
      DVOLW = 0.0                                                        INCN4970
      FXWAV = 0.0                                                        INCN4980
      FYWAV = 0.0                                                        INCN4990
      FZWAV = 0.0                                                        INCN5000
      FKWAV = 0.0                                                        INCN5010
      FMWAV = 0.0                                                        INCN5020
      FNWAV = 0.0                                                        INCN5030
      ZBAR = Z                                                           INCN5040
      PHIBAR = PHI                                                       INCN5050
      THEBAR = THETA                                                     INCN5060
      TIME = STIME                                                       INCN5070
      DELT = DELC                                                        INCN5080
      TPRINT = TPRINO-DELPNT                                             INCN5090
      PWVCON = 4.*WEIGHT/(RHO*G*XLBW)                                    INCN5100
      FNCON = SQRT(XLBW*G)                                               INCN5110
      VX = VXO-XS                                                        INCN5120
      VZ = ZS-VZO                                                        INCN5130
      XP = XPO-XS                                                        INCN5140
      XR = XRO-XS                                                        INCN5150
      YP = YPO                                                           INCN5160
      ZP = ZS-ZPO                                                        INCN5170
      ZR = ZS-ZRO                                                        INCN5180
      IF (IMM.EQ.0) GO TO 65                                             INCN5190
C                                                                        INCN5200
      DO 64 J=1,IMNX                                                     INCN5210
   64 XMI(J) = XMO(J)-XS                                                 INCN5220
C                                                                        INCN5230
   65 CONTINUE                                                           INCN5240
      XCP = XCPO-XS                                                      INCN5250
      ZCP = ZS-BUBHGT                                                    INCN5260
      XBS = XBSI-XS                                                      INCN5270
```

```
      N = NSTA(3)                                                       INCN5280
      ZBS = ZS-ZBSI                                                     INCN5290
C                                                                       INCN5300
      DO 66 J=1,N                                                       INCN5310
      DELYBS = XBBW/(N-1)                                               INCN5320
      XX(3,J) = XBS-XSSI                                                INCN5330
      YY(3,J) = -0.5*XBBW+(J-1)*DELYBS                                  INCN5340
   66 CONTINUE                                                          INCN5350
C                                                                       INCN5360
      N = N-1                                                           INCN5370
C                                                                       INCN5380
      DO 67 J=1,N                                                       INCN5390
      YAVGB(J) = (YY(3,J+1)+YY(3,J))*.5                                 INCN5400
   67 CONTINUE                                                          INCN5410
C                                                                       INCN5420
      N = NSTA(4)                                                       INCN5430
      DELYSS = XBBW/(N-1)                                               INCN5440
C                                                                       INCN5450
      DO 68 J=1,N                                                       INCN5460
      XX(4,J) = -XS                                                     INCN5470
      YY(4,J) = -.5*XBBW+(J-1)*DELYSS                                   INCN5480
   68 CONTINUE                                                          INCN5490
C                                                                       INCN5500
      N = N-1                                                           INCN5510
C                                                                       INCN5520
      DO 69 J=1,N                                                       INCN5530
      YAVGS(J) = (YY(4,J+1)+YY(4,J))*.5                                 INCN5540
   69 CCNTINUE                                                          INCN5550
C                                                                       INCN5560
      XBOW = XLTOT-XS                                                   INCN5570
      N = NSTA(1)                                                       INCN5580
      DELX = XBSI/(N-1)                                                 INCN5590
C                                                                       INCN5600
      DO 70 J=1,2                                                       INCN5610
C                                                                       INCN5620
      DO 70 I=1,N                                                       INCN5630
      XX(J,I) = (I-1)*DELX-XS                                           INCN5640
   70 YY(J,I) = YSW*(2*J-3)                                             INCN5650
C                                                                       INCN5660
      WRITE (6,103) ((XX(J,N),N=1,11),(YY(J,N),N=1,11),J=1,4)           INCN5670
      N = NSTA(1)-1                                                     INCN5680
C                                                                       INCN5690
      DO 71 I=1,N                                                       INCN5700
   71 XAVG(I) = DELX*(2*I-1)*.5-XS                                      INCN5710
C                                                                       INCN5720
C                                                                       INCN5730
      CALL WAVES (TIME)                                                 INCN5740
C                                                                       INCN5750
```

```
C       INITIALIZE BUBBLE PRESSURE, ABSOLUTE (PSF)                                                  INCN5760
C                                                                                                   INCN5770
        PB = PINF+DELPI                                                                             INCN5780
        PBBAR = DELPI                                                                               INCN5790
        PBAR = DELPI                                                                                INCN5800
        PSS = PB+DPSS                                                                               INCN5810
        PBS = PB+DPBS                                                                               INCN5820
        AB = ABW-(ABW-AB)*(ZS+Z/BUBHGT)                                                             INCN5830
        CF = .37/((U/FNCON)**1.5655981)                                                             INCN5840
        WATSLP = PBBAR*CF*PWVCON/WEIGHT                                                             INCN5850
        IF (IDIA.EQ.1) GO TO 72                                                                     INCN5860
        VOL = VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW+.5*WATSLP*XL*AB                                       INCN5870
        GO TO 73                                                                                    INCN5880
   72 VOL = VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW+PBAR*.3175+.5*WATSLP*XL*AB                              INCN5890
   73 CONTINUE                                                                                      INCN5900
        BMASS = (PB/PINF)**(1./GAM)*VOL*RHOINF                                                      INCN5910
        WRITE (6,137)                                                                               INCN5920
        DVWDOT = 0.0                                                                                INCN5930
        RETURN                                                                                      INCN5940
C                                                                                                   INCN5950
C       RUN TERMINATOR                                                                              INCN5960
C                                                                                                   INCN5970
   74 WRITE (6,106)                                                                                 INCN5980
        STOP                                                                                        INCN5990
C                                                                                                   INCN6000
C       BENDING MOMENT                                                                              INCN6010
C                                                                                                   INCN6020
   75 GO TO (76,77,79,81), IOPT                                                                     INCN6030
   76 IMM = TEMP(1)                                                                                 INCN6040
        IF (IMM.GT.3) GO TO 97                                                                      INCN6050
        IMNX = TEMP(2)                                                                              INCN6060
        IF (IMNX.GT.10) GO TO 97                                                                    INCN6070
        IMNY = TEMP(3)                                                                              INCN6080
        IF (IMNY.GT.7) GO TO 97                                                                     INCN6090
        IBMFIL = TEMP(4)                                                                            INCN6100
        BTIME = TEMP(5)                                                                             INCN6110
        IF (IMM.EQ.3) IMT = TEMP(6)                                                                 INCN6120
        GO TO 3                                                                                     INCN6130
C                                                                                                   INCN6140
   77 DO 78 J=1,7                                                                                   INCN6150
   78 XMO(J) = TEMP(J)                                                                              INCN6160
C                                                                                                   INCN6170
        IF (IMNX.LE.7) GO TO 3                                                                      INCN6180
        READ 120, (XMO(J),J=8,IMNX)                                                                 INCN6190
        GO TO 3                                                                                     INCN6200
C                                                                                                   INCN6210
   79 DO 80 J=1,IMNY                                                                                INCN6220
   80 YMI(J) = TEMP(J)                                                                              INCN6230
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C                                                                       INCN6240
      GO TO 3                                                           INCN6250
   81 CONTINUE                                                          INCN6260
      GO TO 3                                                           INCN6270
   82 CONTINUE                                                          INCN6280
      GO TO (83,85,87), IOPT                                            INCN6290
   83 CONTINUE                                                          INCN6300
C                                                                       INCN6310
C  VALUES INPUT FOR STBD SCREW                                          INCN6320
C                                                                       INCN6330
      THST1 = TEMP(1)                                                   INCN6340
      NPS = TEMP(2)                                                     INCN6350
      STHS = TEMP(3)                                                    INCN6360
      IF (NPS.EQ.0.0) GO TO 84                                          INCN6370
      READ (5,104) (TIS(J),J=1,NPS)                                     INCN6380
      READ (5,104) (THSTS(J),J=1,NPS)                                   INCN6390
      GO TO 3                                                           INCN6400
   84 THSTS(1) = THST1                                                  INCN6410
   85 CONTINUE                                                          INCN6420
C                                                                       INCN6430
C  VALUES INPUT FOR PORT SCREW                                          INCN6440
C                                                                       INCN6450
      THST2 = TEMP(1)                                                   INCN6460
      NPP = TEMP(2)                                                     INCN6470
      STHP = TEMP(3)                                                    INCN6480
      IF (NPP.EQ.0.0) GO TO 86                                          INCN6490
      READ (5,104) (TIP(J),J=1,NPP)                                     INCN6500
      READ (5,104) (THSTP(J),J=1,NPP)                                   INCN6510
      GO TO 3                                                           INCN6520
   86 THSTP(1) = THST2                                                  INCN6530
   87 CONTINUE                                                          INCN6540
C                                                                       INCN6550
C  VALUES INPUT FOR RUDDER                                              INCN6560
C                                                                       INCN6570
      DELR = TEMP(1)                                                    INCN6580
      NPR = TEMP(2)                                                     INCN6590
      IF (NPR.EQ.0.0) GO TO 88                                          INCN6600
      READ (5,104) (TIR(J),J=1,NPR)                                     INCN6610
      READ (5,104) (DELRUD(J),J=1,NPR)                                  INCN6620
      GO TO 3                                                           INCN6630
   88 DELRUD(1) = DELR                                                  INCN6640
      GO TO 3                                                           INCN6650
   89 GO TO (90,91), IOPT                                               INCN6660
   90 NB = TEMP(1)                                                      INCN6670
      READ (5,104) (TMEB(I),I=1,NB)                                     INCN6680
      READ (5,104) (DELB(I),I=1,NB)                                     INCN6690
      GO TO 3                                                           INCN6700
   91 NS = TEMP(1)                                                      INCN6710
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      READ (5,104) (TMES(I),I=1,NS)                                    INCN6720
      READ (5,104) (DETS(I),I=1,NS)                                    INCN6730
      GO TO 3                                                          INCN6740
C                                                                      INCN6750
CC    TITLE CARD (ALL 80 COLUMNS )                                     INCN6760
C                                                                      INCN6770
   92 READ (5,136) TITLC                                               INCN6780
      GO TO 3                                                          INCN6790
C                                                                      INCN6800
CC    FAN MAPS                                                         INCN6810
C                                                                      INCN6820
   93 CONTINUE                                                         INCN6830
      GO TO (94,95,96), IOPT                                           INCN6840
   94 CONTINUE                                                         INCN6850
      ENBFAN = TEMP(1)                                                 INCN6860
      BRPM = TEMP(2)                                                   INCN6870
      NPTSB = TEMP(3)                                                  INCN6880
      READIN = TEMP(4)                                                 INCN6890
      IF (READIN.EQ.0.0) GO TO 3                                       INCN6900
      READ (5,104) (PBFAN(J),J=1,NPTSB)                                INCN6910
      READ (5,104) (QBFAN(J),J=1,NPTSB)                                INCN6920
      GO TO 3                                                          INCN6930
   95 CONTINUE                                                         INCN6940
      ENMFAN = TEMP(1)                                                 INCN6950
      EMRPM = TEMP(2)                                                  INCN6960
      NPTSM = TEMP(3)                                                  INCN6970
      READIN = TEMP(4)                                                 INCN6980
      IF (READIN.EQ.0.0) GO TO 3                                       INCN6990
      READ (5,104) (PMFAN(J),J=1,NPTSM)                                INCN7000
      READ (5,104) (QMFAN(J),J=1,NPTSM)                                INCN7010
      GO TO 3                                                          INCN7020
   96 CONTINUE                                                         INCN7030
      ENSFAN = TEMP(1)                                                 INCN7040
      SRPM = TEMP(2)                                                   INCN7050
      NPTSS = TEMP(3)                                                  INCN7060
      READIN = TEMP(4)                                                 INCN7070
      IF (READIN.EQ.0.0) GO TO 3                                       INCN7080
      READ (5,104) (PSFAN(J),J=1,NPTSS)                                INCN7090
      READ (5,104) (QSFAN(J),J=1,NPTSS)                                INCN7100
      GO TO 3                                                          INCN7110
C                                                                      INCN7120
CC    ERROR IN INPUT                                                   INCN7130
C                                                                      INCN7140
   97 CONTINUE                                                         INCN7150
      WRITE (6,105) ISYS                                               INCN7160
      STOP                                                             INCN7170
C                                                                      INCN7180
C                                                                      INCN7190
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 98 FORMAT (2I2)                                                        INCN7200
 99 FORMAT (26I2)                                                       INCN7210
100 FORMAT (6A8)                                                        INCN7220
101 FORMAT (10I1)                                                       INCN7230
102 FORMAT (8I2)                                                        INCN7240
103 FORMAT (//17H XX AND YY ARRAYS/14H PORT SIDEWALL/2(11F10.2/),15H S  INCN7250
   1TBD. SIDEWALL/2(11F10.2/),9H BOW SEAL/2(11F10.2/),11H STERN SEAL/2  INCN7260
   2(11F10.2/))                                                         INCN7270
104 FORMAT (8F10.0)                                                     INCN7280
105 FORMAT (34H INPUT ERROR - - - STOP - -  ISYS=,I3)                   INCN7290
106 FORMAT (1H1,20(/),50X,19H COMPLETED ALL RUNS)                       INCN7300
107 FORMAT (I3,I2,7F10.0)                                               INCN7310
108 FORMAT (16I5)                                                       INCN7320
109 FORMAT (5F10.0)                                                     INCN7330
110 FORMAT (///10X,65HERROR IN INPUT --- DELT AND/OR DELPNT EQUALS ZERINCN7340
   10 --- JOB ABORTED)                                                  INCN7350
111 FORMAT (2I2/(8F10.0))                                               INCN7360
112 FORMAT (22H INERTIA MATRIX, AIMAX6F15.4/(22X,6F15.4))               INCN7370
113 FORMAT (30H WEIGHT, C.G., INERTIA MOMENTS7F12.3)                    INCN7380
114 FORMAT (15H SIDEWALL INPUT12(F8.3,1X))                              INCN7390
115 FORMAT (26H SIDEWALL TABLE PARAMETERS4(I4,F7.3,F7.3))               INCN7400
116 FORMAT (2F10.0)                                                     INCN7410
117 FORMAT (/12HONO OF WAVESI2,10H BETA(DEG)F5.0/15H OMEGA(RAD/SEC),5X  INCN7420
   1,16H OMEGAE(RAD/SEC)5X,16H WAVE LENGTH(FT)5X,14H AMPLITUDE(FT)5X,1  INCN7430
   26HMAX  SLOPE (DEG)5X,13HPERIOD,E(SEC)/(F8.4,12X,F8.4,4F20.3))       INCN7440
118 FORMAT (/11HOCALM WATER)                                            INCN7450
119 FORMAT (32HOMOMENT CALC. CONTROL PARAMETERS4I5,F8.3,I5)             INCN7460
120 FORMAT (5X,7F10.0)                                                  INCN7470
121 FORMAT (22H MOMENT CALCS. AT X OF11F10.3)                           INCN7480
122 FORMAT (22H MOMENT CALCS. AT Y OF11F10.3)                           INCN7490
123 FORMAT (33H1SES MOTIONS AND LOADS PROGRAM - 20A4,/)                 INCN7500
124 FORMAT (23H START AND FINISH TIMES2F10.2/22H INITIAL TIME INTERVAL  INCN7510
   1F12.4/18H START PRINTING ATF8.2,17H IN INCREMENTS OFF8.2)           INCN7520
125 FORMAT (24H INTERMEDIATE PRINT TAGS16I5)                            INCN7530
126 FORMAT (39H NO. OF STATE EQUATIONS, AND TOLERANCESI5/(10X,10E12.2)  INCN7540
   1)                                                                   INCN7550
127 FORMAT (23HOCRITICAL FROUDE NUMBERF15.4,5X,19H TOTAL CRAFT LENGTHF  INCN7560
   115.4)                                                               INCN7570
128 FORMAT (34HOPLENUM, LENGTH AND WIDTH AT WATER2F12.4)                INCN7580
129 FORMAT (34H PLENUM, LENGTH AND WIDTH AT HULL 2F12.4/35H PLENUM, CE  INCN7590
   1NTER OF PRESSURE AT HULLF12.4/23H PLENUM, NOMINAL VOLUMEF12.1,10X,  INCN7600
   26HHEIGHTF12.4)                                                      INCN7610
130 FORMAT (/33H PROPULSION, X, Y, Z COORDINATES 3F12.4/)               INCN7620
131 FORMAT (/28HORUDDER, X, Y, Z COORDINATES3F12.4/41H RUDDER, ON, MAX  INCN7630
   1, RATE, REVERSE, INITIAL 5F12.4/33H RUDDER,SPAN,ASPECT,AREA,CLB,T/  INCN7640
   2C 5F12.4)                                                           INCN7650
132 FORMAT (/39HOINITIAL CONDITIONS, VELOCITY (KNOTS) =F7.2,5X,13HPITC  INCN7660
   1H (DEG) =F8.3,5X,12HDRAFT (IN) =F8.2)                               INCN7670
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  133 FORMAT (49H NUMBER OF STATIONS, SIDEWALLS (P+S), SEALS (B+S),4I5)  INCN7680
  134 FORMAT (38H PLENUM, INITIAL PRESSURE, GAGE (PSF) F8.2)            INCN7690
  135 FORMAT (79H PROGRAM OPTION SWITCH SETTINGS (LATERAL PLANE,CONSTANTINCN7700
     1 SPEED,TRIM,MEMBRANE)   7I5)                                     INCN7710
  136 FORMAT (20A4)                                                    INCN7720
  137 FORMAT (1H1)                                                     INCN7730
  138 FORMAT (16H STERNSEAL INPUT7F12.4)                               INCN7740
  139 FORMAT (16H BOWSEAL INPUT  7F12.4)                               INCN7750
  140 FORMAT (19HOAERODYNAMICS INPUT7F12.4)                            INCN7760
  141 FORMAT (33HOFANS, NO. + RPM, BOW,MAIN,STERN 3(F10.0,F10.1))      INCN7770
  142 FORMAT (32H PROGRAM MODIFICATION SETTINGS  7(F12.4,1X))          INCN7780
      END                                                              INCN7790

      SUBROUTINE INTGRL (TIME)                                         INT    10
      INTEGER CN                                                       INT    20
      COMMON /AIR/ PINF,RHOINF,GAM                                     INT    30
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY INT    40
      COMMON /EQNCO/ NEQS,TOL(20),JQQ                                  INT    50
      COMMON /KSWTCH/ ITHRST                                           INT    60
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMINT    70
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                        INT    80
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA                           INT    90
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,PMDOT          INT   100
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                    INT   110
      COMMON /PROMOD/ PROMO1,PROMO2, PROMO3, PROMO4, PROMO5, PROMO6, PROMO7  INT   120
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IINT   130
     1RUD,IPROP,IAEROD,IRHS                                            INT   140
      COMMON /STABLE/ S(4),ISTAB                                       INT   150
      COMMON /STEP/ STEP2                                              INT   160
      COMMON /VALOLD/ YOLD(20)                                         INT   170
      COMMON /VARBLE/ VAL(40)                                          INT   180
      EQUIVALENCE (VAL(1),X), (VAL(2),Y(1))                            INT   190
      DIMENSION Y(20), ERROR(20)                                       INT   200
      REAL K1(20),K2(20),K3(20),K4(20),K5(20)                          INT   210
      DATA IPASS/0/                                                    INT   220
      STEP2 = 1.0                                                      INT   230
      PB = VAL(24)                                                     INT   240
      BMASS = Y(10)                                                    INT   250
      IF ((TIME+DELT).LE.TPRINT) GO TO 1                               INT   260
      DEL = DELT                                                       INT   270
      DELT = TPRINT-TIME                                               INT   280
      IPASS = 1                                                        INT   290
    1 X = TIME                                                         INT   300
C                                                                      INT   310
      DO 2 J=1,NEQS                                                    INT   320
      Y(J) = YOLD(J)                                                   INT   330
    2 CONTINUE                                                         INT   340
C                                                                      INT   350
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      ITHRST = 1                                                        INT   360
      CALL RHS (K1)                                                     INT   370
      ITHRST = 2                                                        INT   380
      IMT = 0                                                           INT   390
      IF (IACCEL.NE.ON) GO TO 3                                         INT   400
      ACCLAT = (K1(2)+Y(1)*Y(6))/G                                      INT   410
      WRITE (6,20) ACCLAT,DELT                                          INT   420
    3 ON = 2                                                            INT   430
    4 H = DELT/3.                                                       INT   440
      X = TIME+H                                                        INT   450
C                                                                       INT   460
      DO 5 J=1,NEQS                                                     INT   470
    5 Y(J) = YOLD(J)+H*K1(J)                                            INT   480
C                                                                       INT   490
      CALL RHS (K2)                                                     INT   500
C                                                                       INT   510
      DO 6 J=1,NEQS                                                     INT   520
    6 Y(J) = YOLD(J)+.5*H*(K1(J)+K2(J))                                 INT   530
C                                                                       INT   540
      CALL RHS (K3)                                                     INT   550
      X = TIME+.5*DELT                                                  INT   560
C                                                                       INT   570
      DO 7 J=1,NEQS                                                     INT   580
    7 Y(J) = YOLD(J)+.375*H*(K1(J)+3.*K3(J))                            INT   590
C                                                                       INT   600
      CALL RHS (K4)                                                     INT   610
      X = TIME+DELT                                                     INT   620
C                                                                       INT   630
      DO 8 J=1,NEQS                                                     INT   640
    8 Y(J) = YOLD(J)+.5*H*(3.*K1(J)-9.*K3(J)+12.*K4(J))                 INT   650
C                                                                       INT   660
      CALL RHS (K5)                                                     INT   670
      IF (JCC.EQ.1) GO TO 9                                             INT   680
C                                                                       INT   690
      DO 9 J=1,NEQS                                                     INT   700
      ERROR(J) = (K1(J)-4.5*K3(J)+4.*K4(J)-.5*K5(J))*H/5.0              INT   710
      IF (ABS(ERROR(J)).GT.TOL(J)) GO TO 15                             INT   720
    9 CONTINUE                                                          INT   730
C                                                                       INT   740
C                                                                       INT   750
      DO 10 J=1,NEQS                                                    INT   760
      Y(J) = YOLD(J)+.5*H*(K1(J)+4.*K4(J)+K5(J))                        INT   770
   10 YOLD(J) = Y(J)                                                    INT   780
C                                                                       INT   790
      TIME = TIME+DELT                                                  INT   800
      IF (IPASS.EQ.1) GO TO 14                                          INT   810
      IF (JCC.EQ.1) GO TO 12                                            INT   820
C                                                                       INT   830
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      DO 11 J=1,NEQS                                                    INT  840
      IF (ABS(ERROR(J)).GT.TOL(J)/16.) GO TO 13                         INT  850
   11 CONTINUE                                                          INT  860
C                                                                       INT  870
      DELT = 2.*DELT                                                    INT  880
      IF (DELT.GT.DELPNT) DELT=DELPNT                                   INT  890
   12 RETURN                                                            INT  900
   13 STEP2 = DELT                                                      INT  910
      GO TO 12                                                          INT  920
   14 DELT = DEL                                                        INT  930
      IPASS = 0                                                         INT  940
      GO TO 12                                                          INT  950
   15 DELT = DELT/2.                                                    INT  960
      IF (DELT.LT.1.E-6) GO TO 18                                       INT  970
      IF (JQQ.EQ.2) GO TO 17                                            INT  980
      WRITE (6,22) TIME,DELT,J,ERROR(J),TOL(J)                          INT  990
   16 IPASS = 0                                                         INT 1000
      GO TO 4                                                           INT 1010
   17 STEP1 = DELT*2.0                                                  INT 1020
      IF (STEP1.LT.STEP2) STEP2=STEP1                                   INT 1030
      GO TO 16                                                          INT 1040
   18 WRITE (6,21)                                                      INT 1050
      WRITE (6,19) TIME,DELT,(K1(J),J=1,NEQS),VAL                       INT 1060
      STOP                                                              INT 1070
C                                                                       INT 1080
   19 FORMAT (/10X,23HINTGRL TIME,DELT,K1,VAL/2E15.4/2(6E15.4/),5(8E15.4INT 1090
     1/))                                                               INT 1100
   20 FORMAT (1H0,9X,33HTOTAL LATERAL ACCELERATION (G) = F12.4,12X,5HDT  INT 1110
     1= E15.4)                                                          INT 1120
   21 FORMAT (1H1,10X,44HDELTA TIME LESS THAN 1.0E-6  -  -  JOB STOPS)  INT 1130
   22 FORMAT (/10X,5HINT-J2E30.5,I5,2E20.5)                             INT 1140
      END                                                               INT 1150

      SUBROUTINE PROP                                                   PROP  10
C                                                                       PROP  20
      INTEGER ON                                                        PROP  30
      COMMON /CONST/ PI,RAD,UO                                          PROP  40
      COMMON /FPROP/ FX,FY,FZ,FK,FM,FN                                  PROP  50
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIPPROP  60
     1(25),TIS(25)                                                      PROP  70
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IPROP  80
     1RUD,IPROP,IAEROD,IRHS                                             PROP  90
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  PROP 100
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,RPROP 110
     1CLB,RTC,RUDANG,TIR(25)                                            PROP 120
      COMMON /VARBLE/ VAL(40)                                           PROP 130
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAPROP 140
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAPROP 150
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     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)PROP  160
     3, (VAL(24),PB)                                                    PROP  170
      DIMENSION THS(1), THP(1), TS(1), TP(1), RUD(1), TR(1)             PROP  180
      EQUIVALENCE (THSTS(1),THS(1)), (THSTP(1),THP(1)), (TIS(1),TS(1)),  PROP  190
     1(TIP(1),TP(1)), (TIR(1),TR(1)), (DELRUD(1),RUD(1))                PROP  200
C                                                                       PROP  210
      FX = 0.0                                                          PROP  220
      FY = 0.0                                                          PROP  230
      FZ = 0.0                                                          PROP  240
      FK = 0.0                                                          PROP  250
      FM = 0.0                                                          PROP  260
      FN = 0.0                                                          PROP  270
      TL = TIME                                                         PROP  280
      IF (NPR.EQ.0.0) GO TO 1                                           PROP  290
      RUDANG = FG1(TL,NPR,TR,RUD,IR)                                    PROP  300
      RUDANG = RUDANG/RAD                                               PROP  310
C                                                                       PROP  320
C     CALCULATE THRUSTS AND MOMENTS INDIVIDUALLY                        PROP  330
C                                                                       PROP  340
      GO TO 2                                                           PROP  350
    1 RUDANG = DELRUD(1)                                                PROP  360
      RUDANG = RUDANG/RAD                                               PROP  370
    2 CD = CCS(RUDANG)                                                  PROP  380
      SD = SIN(RUDANG)                                                  PROP  390
      IF (NPS.EQ.0.0) GO TO 3                                           PROP  400
      THSS = FG1(TL,NPS,TS,THS,IS)                                      PROP  410
      GO TO 4                                                           PROP  420
    3 THSS = THSTS(1)                                                   PROP  430
    4 IF (NPP.EQ.0.0) GO TO 5                                           PROP  440
      THSP = FG1(TL,NPP,TP,THP,IP)                                      PROP  450
      GO TO 6                                                           PROP  460
    5 THSP = THSTP(1)                                                   PROP  470
    6 STHSTS = STHS*THSS                                                PROP  480
      STHSTP = STHP*THSP                                                PROP  490
      FXS = THSS*CD-STHSTS*SD                                           PROP  500
      FXP = THSP*CD+STHSTP*SD                                           PROP  510
      FYS = -STHSTS*CD-THSS*SD                                          PROP  520
      FYP = STHSTP*CD+SD*THSP                                           PROP  530
      FZS = -THSS*THETA*CD+STHSTS*SD*PHI                                PROP  540
      FZP = -THSP*THETA*CD-STHSTP*SD*PHI                                PROP  550
      FX = FXP+FXS                                                      PROP  560
      FY = FYP+FYS                                                      PROP  570
      FZ = FZP+FZS                                                      PROP  580
      FKP = -FZP*YP-FYP*ZP                                              PROP  590
      FKS = FZS*YP-FYS*ZP                                               PROP  600
      FK = FKS+FKP                                                      PROP  610
      FMS = FZS*(-XP)+FXS*ZP                                            PROP  620
      FMP = FZP*(-XP)+FXP*ZP                                            PROP  630
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      FM = FMS+FMP                                                          PROP  640
      FNS = -FXS*YP-FYS*(-XP)                                               PROP  650
      FNP = FXP*YP-FYP*(-XP)                                                PROP  660
      FN = FNS+FNP                                                          PROP  670
      IF (IPROP.NE.ON) RETURN                                               PROP  680
      WRITE (6,7) FX,FY,FZ,FK,FM,FN                                         PROP  690
      RETURN                                                                PROP  700
C                                                                           PROP  710
    7 FORMAT (/10X,22HPPROP FX,FY,FZ,FK,FM,FN/6F15.4)                       PROP  720
      END                                                                   PROP  730

      SUBROUTINE RUDDER                                                     RUD    10
C                                                                           RUD    20
      INTEGER ON                                                            RUD    30
      COMMON /CONST/ PI,RAD,U0                                              RUD    40
      COMMON /FRUD/ FX,FY,FZ,FK,FM,FN                                       RUD    50
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMRUD    60
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                             RUD    70
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7      RUD    80
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD    90
     1RUD,IPROP,IAEROD,IRHS                                                 RUD   100
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,RRUD   110
     1CLB,RTC,RUDANG,TIR(25)                                                RUD   120
      COMMON /VARBLE/ VAL(40)                                               RUD   130
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VARUD   140
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VARUD   150
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)RUD   160
     3, (VAL(24),PB)                                                        RUD   170
      EQUIVALENCE (DELRUD(1),RUD(1)), (TIR(1),TR(1))                        RUD   180
      DIMENSION RUD(1), TR(1)                                               RUD   190
      EQUIVALENCE (VAL(18),FANPWR)                                          RUD   200
      DATA ENU/1.28E-5/                                                     RUD   210
C                                                                           RUD   220
C     CALCULATE PROGRAMMED RUDDER DEFLECTION                                RUD   230
C                                                                           RUD   240
      TL = TIME                                                             RUD   250
      IF (NPR.EQ.0.0) GO TO 1                                               RUD   260
      GO TO 2                                                               RUD   270
    1 RUDANG = DELRUD(1)                                                    RUD   280
      RUDANG = RUDANG/RAD                                                   RUD   290
      GO TO 3                                                               RUD   300
    2 RUDANG = FG1(TL,NPR,TR,RUD,IR)                                        RUD   310
      RUDANG = RUDANG/RAD                                                   RUD   320
C                                                                           RUD   330
C     SIDE FORCE ON RUDDER                                                  RUD   340
C                                                                           RUD   350
    3 DSR = Z+ZS-XR*THETA                                                   RUD   360
      ENDFAC = (1.+DSR/(DSR+RSPAN))                                         RUD   370
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      VH = V+XR*R-ZR*P                                                  RUD   380
      QQ = HRHO*U*U*RAREA                                               RUD   390
      EFFANG = RUDANG-ENDFAC*VH/U                                       RUD   400
      FY = 2.*QQ*ENDFAC*RCLB*EFFANG                                     RUD   410
C                                                                       RUD   420
C     DRAG FORCE ON RUDDER                                              RUD   430
C                                                                       RUD   440
      REY = U*(RAREA/RSPAN)/ENU                                         RUD   450
      CFR = .427/(ALOG10(REY)-.407)**2.64                               RUD   460
      PI8 = PI/8.                                                       RUD   470
      CD = 2.*CFR+PI8*RTC*RTC*(1.+G*RSPAN/(U*U))+RCLB*EFFANG*EFFANG     RUD   480
      FX = -2.*CD*RAREA*HRHO*U*U                                        RUD   490
      FZ = 0.                                                           RUD   500
      FK = -ZR*FY                                                       RUD   510
      FM = FX*ZR                                                        RUD   520
      FN = XR*FY                                                        RUD   530
      IF (IRUD.NE.ON) RETURN                                            RUD   540
      WRITE (6,4) FX,FY,FZ,FK,FM,FN                                     RUD   550
C                                                                       RUD   560
C                                                                       RUD   570
      RETURN                                                            RUD   580
C                                                                       RUD   590
    4 FORMAT (/10X,24HRUDDER FX,FY,FZ,FK,FM,FN/6E15.4)                  RUD   600
      END                                                               RUD   610

      SUBROUTINE RHS (VALUF)                                            RHS    10
      INTEGER ON                                                        RHS    20
      COMMON /AIR/ PINF,RHOINF,GAM                                      RHS    30
      COMMON /ATPIX/ AMASSI,AIYYI,DIXX,DIXZ,DIZZ                        RHS    40
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY RHS    50
      COMMON /COLUMN/ IVERT,ILATRL                                      RHS    60
      COMMON /CONST/ PI,RAD,UO                                          RHS    70
      COMMON /CNTRL/ CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUIRHS    80
     1L,THEQL,ACBASE                                                    RHS    90
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIPRHS   100
     1(25),TIS(25)                                                      RHS   110
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,ENRHS   120
     1SFAN,BRPM,MRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(25RHS   130
     2),TMEB(25),DELB(25),NB,TMES(25),DETS(25),NS                       RHS   140
      COMMON /FAERO/ FXAED,FYAED,FZAED,FKAED,FMAED,FNAED                RHS   150
      COMMON /FORBS/ FXBS,FYBS,FZBS,FKBS,FMBS,FNBS,QLBS                 RHS   160
      COMMON /FORSS/ FXSS,FYSS,FZSS,FKSS,FMSS,FNSS,QLSS,FMS             RHS   170
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP                            RHS   180
      COMMON /FROUDE/ FN,FNCRIT                                         RHS   190
      COMMON /FRUD/ FXRUD,FYRUD,FZRUD,FKRUD,FMRUD,FNRUD                 RHS   200
      COMMON /GBOW/ XBOW                                                RHS   210
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,RHS   220
     110),XCP,ZCP                                                       RHS   230
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      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)RHS  240
     1,TSKIE(10)                                                        RHS  250
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)RHS  260
     1,ARM2S(10)                                                        RHS  270
      COMMON /KSWTCH/ ITHRST                                            RHS  280
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMRHS  290
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         RHS  300
      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FNRHS  310
     1H(2),VFY(2),VFZ(2),FXV                                            RHS  320
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)          RHS  330
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA                            RHS  340
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,CMM             RHS  350
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                     RHS  360
      COMMON /PRTNT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRHS  370
     1RUD,IPROP,IAEROD,IRHS                                             RHS  380
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  RHS  390
      COMMON /PWAVE/ FNCON,PWVCON                                       RHS  400
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,RRHS  410
     1CLB,RTC,RUDANG,TIR(25)                                            RHS  420
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSRHS  430
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC         RHS  440
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    RHS  450
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVRHS  460
     1GB(10),CENCAB                                                     RHS  470
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVRHS  480
     1GS(10)                                                            RHS  490
      COMMON /VALOLD/ YOLD(20)                                          RHS  500
      COMMON /VARBLE/ VAL(40)                                           RHS  510
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYRHS  520
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBRHS  530
     2BAR                                                               RHS  540
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VARHS  550
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VARHS  560
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)RHS  570
     3, (VAL(24),PB)                                                    RHS  580
      EQUIVALENCE (VAL(18),FANPWR)                                      RHS  590
      DIMENSION ACCEL(3), ANGACL(3)                                     RHS  600
      DIMENSION GF(6), VALUE(20)                                        RHS  610
      DATA CCF/4.9E-07/                                                 RHS  620
C                                                                       RHS  630
C                                                                       RHS  640
      DO 1 J=1,20                                                       RHS  650
    1 VALUE(J) = 0.0                                                    RHS  660
C                                                                       RHS  670
CCC                                                                     RHS  680
CC    CALCULATION OF BUBBLE WAVE MAKING DRAG                            RHS  690
C                                                                       RHS  700
      AB = ABW-(ABW-(XL*WIDTH))*(ZS+Z)/BUBHGT                           PHS  710
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      FN = U/FNCON                                                          RHS  720
      CF = .37/(FN**1.5655981)                                              RHS  730
      FXPWAV = -PWVCON*PBBAR*CF                                             RHS  740
      WATSLP = -FXPWAV/WEIGHT                                               RHS  750
      VOL = VAL(12)                                                         RHS  760
      PB = VAL(13)                                                          RHS  770
      PBAR = VAL(13)-PINF                                                   RHS  780
      PBS = PB+DPBS                                                         RHS  790
      PSS = PB+DPSS                                                         RHS  800
      ABPB = PBAR*AB                                                        RHS  810
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                                RHS  820
C                                                                           RHS  830
      FLOW = SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)                        RHS  840
      CLSW = CFSW*ALSW*FLOW                                                 RHS  850
C                                                                           RHS  860
      CALL BOWSL                                                            RHS  870
      CALL STNSL                                                            RHS  880
C                                                                           RHS  890
      SUMX = FXBS+FXSS+FXSW+FXRUD+FXP+FXWAV+FXAED+FXPWAV                    RHS  900
      IF (ITHRST.NE.ITRIM) GO TO 2                                          RHS  910
      THSTS(1) = THSTS(1)-SUMX*.5                                           RHS  920
      THSTP(1) = THSTP(1)-SUMX*.5                                           RHS  930
      THST = THSTS(1)+THSTP(1)                                              RHS  940
      SUMX = 0.0                                                            RHS  950
    2 CONTINUE                                                              RHS  960
      SUMY = FYBS+FYSS+FYSW+FYRUD+FYP+FYWAV+FYAED                           RHS  970
      SUMZ = WEIGHT-ABPB+FZBS+FZSS+FZSW+FZRUD+FZP+FZWAV+FZAED               RHS  980
      SUMK = FKBS+FKSS+FKSW+FKRUD+FKP+FKWAV+FKAED+ABPB*PHI*(-Z)             RHS  990
C                                                                           RHS 1000
C     CALCULATION OF EFFECTIVE CENTER OF PRESSURE                           RHS 1010
C                                                                           RHS 1020
      UU = U*0.5921-30.0                                                    RHS 1030
      XCPU = XCP+0.001975*UU*UU-0.974                                       RHS 1040
      XCPC = SHXYAX(XCPU,ZCP,THETA,PI)                                      RHS 1050
      FMBUB = ABPB*XCPC                                                     RHS 1060
      SUMM = FMBS+FMSS+FMSW+FMRUD+FMP+FMWAV+FMAED+FMBUB+FXPWAV*ZS           RHS 1070
      FWAVZ = FXPWAV*ZS                                                     RHS 1080
      SUMN = FNBS+FNSS+FNSW+FNRUD+FNP+FNWAV+FNAED                           RHS 1090
      IF (I3DOF.NE.1) GO TO 3                                               RHS 1100
      SUMZ = 0.0                                                            RHS 1110
      SUMM = 0.0                                                            RHS 1120
    3 CONTINUE                                                              RHS 1130
      VALUE(1) = SUMX*AMASSI                                                RHS 1140
      VALUE(2) = SUMY*AMASSI-R*U                                            RHS 1150
      VALUE(3) = SUMZ*AMASSI                                                RHS 1160
      VALUE(4) = SUMK*DIZZ+SUMN*DIXZ                                        RHS 1170
      VALUE(5) = SUMM*AIYYI                                                 RHS 1180
      VALUE(6) = SUMN*DIXX+SUMK*DIXZ                                        RHS 1190
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      VALUE(7) = P                                                                  RHS 1200
      VALUE(8) = Q                                                                  RHS 1210
      VALUE(9) = W                                                                  RHS 1220
      IF (I3DOF.EQ.1) GO TO 6                                                       RHS 1230
C                                                                                   RHS 1240
CC    BUBBLE PRESSURE EQUATION                                                      RHS 1250
C                                                                                   RHS 1260
      QOUT = QLBS+QLSS+QLSW                                                         RHS 1270
C                                                                                   RHS 1280
      CALL FAN                                                                      RHS 1290
      VALUE(10) = RHOINF*(QIN-QOUT)                                                 RHS 1300
      VALUE(11) = -(((XL*WIDTH)+ABW)*.5)*W-DVWDOT                                   RHS 1310
      VALUE(12) = VAL(13)*GAM*((VALUE(10)/VAL(11))-(VALUE(11)/VAL(12)))             RHS 1320
      IF (IDIA.EQ.1) GO TO 4                                                        RHS 1330
      GO TO 5                                                                       RHS 1340
    4 CONTINUE                                                                      RHS 1350
C                                                                                   RHS 1360
CC    MEMBRANE STUDY                                                                RHS 1370
C                                                                                   RHS 1380
      VAL(12)=VAL(12)+0.3175*VAL(13)                                                RHS 1390
      VALUE(12)=VAL(13)*GAM*((VALUE(10)/VAL(11))-(VALUE(11)/VAL(12)))               RHS 1400
    5 CONTINUE                                                                      RHS 1420
      GO TO 7                                                                       RHS 1430
    6 CONTINUE                                                                      RHS 1440
      VALUE(10) = 0.0                                                               RHS 1450
    7 CONTINUE                                                                      RHS 1460
C                                                                                   RHS 1470
CC    WRITE DATA FILE FOR MOMENT AND SHEAR CALCS., IF REQUIRED                      RHS 1480
C                                                                                   RHS 1490
      IF (IMT.NE.1) GO TO 8                                                         RHS 1500
      NBS = NSTA(3)-1                                                               RHS 1510
      NSS = NSTA(4)-1                                                               RHS 1520
      NSSL = NSS/2+1                                                                RHS 1530
      WRITE (IBMFIL) (VAL(I),I=1,24),ZBAR,PHIBAR,THEBAR,FXW,FYW,FZW,FKW,           RHS 1540
     1FMW,FNW,(VALUE(I),I=1,10),DF,DSWAV,FXH,FYH,FZH,FMH,FNH,VFY,VFZ,FXV          RHS 1550
     2,FXRUD,FYRUD,FXP,FYP,FZP,FZSS,FKSS,FMSS,FXBS,FZBS,FXAED,FYAED,FZAE          RHS 1560
     3D,FMAED,FNAED,FXPWAV,FXSS,FKBS,FMBS,FNBS,FNSS,(TSKIS(I),DFSS(I),I=          RHS 1570
     4NSSL,NSS),(TSKIB(I),DFBS(I),ARM1B(I),ARM2B(I),I=1,NBS)                       RHS 1580
    8 CONTINUE                                                                      RHS 1590
C                                                                                   RHS 1600
CC    CONSTANT LONGITUDINAL VELOCITY ( U )                                          RHS 1610
C                                                                                   RHS 1620
      IF (ISRGE.EQ.1) VALUE(1)=0.0                                                  RHS 1630
      IF (ON.NE.1) RETURN                                                           RHS 1640
C                                                                                   RHS 1650
      DO 9 I=1,3                                                                    RHS 1660
      ACCEL(I) = VALUE(I)/G                                                         RHS 1670
      ANGACL(I) = VALUE(I+3)*RAD                                                    RHS 1680
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    9 CONTINUE                                                                RHS 1690
C                                                                             RHS 1700
      BOWACC = ACCEL(3)-XBOW*VALUE(5)/G                                       RHS 1710
      STNACC = ACCEL(3)+XS*VALUE(5)/G                                         RHS 1720
      IF (IVERT.NE.ON) GO TO 10                                               RHS 1730
      ZD = Z+ZS                                                               RHS 1740
      VOLP = VOL                                                              RHS 1750
      THETAR = THETA*RAD                                                      RHS 1760
      QDEG = Q*RAD                                                            RHS 1770
   10 IF (ILATRL.NE.ON) GO TO 13                                              RHS 1780
      DEPSI = PSI*RAD                                                         RHS 1790
      PDEG = P*RAD                                                            RHS 1800
      RDEG = R*RAD                                                            RHS 1810
      BETAS = -V/U*RAD                                                        RHS 1820
      ACCLAT = (VALUE(2)+U*R)/G                                               RHS 1830
      DPHI = PHI*RAD                                                          RHS 1840
      DRFT = 12.0*ZD                                                          RHS 1850
      VEL = 0.5925*U                                                          RHS 1860
      DELRS = RUDANG*RAD                                                      RHS 1870
      IF (R.EQ.0.0) GO TO 11                                                  RHS 1880
      TRADUS = U/R                                                            RHS 1890
      GO TO 12                                                                RHS 1900
   11 TRADUS = 1.E8                                                           RHS 1910
   12 WRITE (1) TIME,VAL(16),DRFT,THETAR,PBAR,BOWACC,ACCEL(3),FANPWR,DPHRHS 1920
     1I,DEPSI,ACCLAT,VEL,TRADUS,VOLP,X,Y,QIN,QOUT,GF(1),FXPWAV,THSTS(1),RHS 1930
     2THSTP(1),QDEG,PDEG,RDEG,DELRS                                           RHS 1940
   13 IF (IRHS.NE.ON) RETURN                                                  RHS 1950
      WRITE (6,14) FMBS,FMSS,FMSW,FMRUD,FMP,FMWAV,FMAED,FMBUB,FWAVZ           RHS 1960
      WRITE (6,15) FXPWAV                                                     RHS 1970
      WRITE (6,16) PBAR,FANPWR,QIN,QLBS,QLSW,QLSS                             RHS 1980
      WRITE (6,17) AB,VOL                                                     RHS 1990
      WRITE (6,18) VALUE,VAL                                                  RHS 2000
      WRITE (6,19) GF,ACCEL,ANGACL                                            RHS 2010
      WRITE (6,20) BOWACC,STNACC                                              RHS 2020
C                                                                             RHS 2030
C                                                                             RHS 2040
      RETURN                                                                  RHS 2050
C                                                                             RHS 2060
   14 FORMAT ('0',6X,5HFMBS=,E16.6,2X,5HFMSS=,F16.6,2X,5HFMSW=,               RHS 2070
     1 E16.6,/,'0',6X,6HFMRUD=,E16.6,2X,4HFMP=,E16.6,2X,6HFMWAV=,E16.6,      RHS 2080
     2 /,'0',6X,6HFMAED=,E16.6,2X,6HFMBUB=,E16.6,2X,6HFWAVZ=,E16.6)           RHS 2090
   15 FORMAT ('0',6X,7HFXPWAV=,E16.6)                                         RHS 2100
   16 FORMAT (//10X,3HPHS20HGAGEPRESS.(PSF)=F7.2,5X,21HFAN POWER REQD (HRHS 2110
     1P) =F8.2,5X,27HFAN FLOW RATE (CU FT/SEC) =F9.2,//31H LEAKAGE FLOW RHS 2120
     2RATES (CU FT/SEC)//11H BOW SEAL =F9.2,11H SIDEWALL =F9.2,13H STERNRHS 2130
     3 SEAL =F9.2)                                                            RHS 2140
   17 FORMAT (/13H PLENUM AREA=F9.2,10X,14HPLENUM VOLUME=F10.2)               RHS 2150
   18 FORMAT (//12H VALUE ARRAY2(/10E13.4)/10H VAL ARRAY4(/10E13.4))          RHS 2160
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   19 FORMAT (/10X,24HTOTAL FORCES AND MOMENTS6E12.4/10X,24HACCELERATIONRHS  2170
     1S G,DEG/SEC26E12.4)                                                RHS  2180
   20 FORMAT (/10X,16HBOW ACCEL. (G) =F12.4,21H   STERN ACCEL. (G) =E12.RHS  2190
     14)                                                                 RHS  2200
      END                                                                RHS  2210

      SUBROUTINE SAM                                                     SAM    10
C                                                                        SAM    20
      WRITE (6,1)                                                        SAM    30
      RETURN                                                             SAM    40
C                                                                        SAM    50
    1 FORMAT (1H1,'YOU HAVE CALLED A DUMMY SAM SUBROUTINE.'/             SAM    60
     110X,'CHANGE TO BH1SES TO USE THE SAM SUBROUTINE.')                 SAM    70
      END                                                                SAM    80

      SUBROUTINE SIDEWL                                                  SDWL   10
C                                                                        SDWL   20
      INTEGER ON                                                         SDWL   30
      COMMON /AIR/ PINF,RHOINF,GAM                                       SDWL   40
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY  SDWL   50
      COMMON /CONST/ PI,RAD,UO                                           SDWL   60
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,SDWL   70
     110),XCP,ZCP                                                        SDWL   80
      COMMON /GEOMSW/ XAVG(10),DS                                        SDWL   90
      COMMON /KSWTCH/ ITHRST                                             SDWL  100
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMSDWL  110
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                          SDWL  120
      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FNSDWL  130
     1H(2),VFY(2),VFZ(2),FXV                                             SDWL  140
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT                        SDWL  150
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                      SDWL  160
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,ISDWL  170
     1RUD,IPROP,IAEROD,IRHS                                              SDWL  180
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   SDWL  190
      COMMON /SIDE/ FX,FY,FZ,FK,FM,FN,ALSW,YSW,XLSW,CFSW,CDSW,VAREA,VCHOSDWL  200
     1RD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC                      SDWL  210
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                     SDWL  220
      COMMON /VARBLE/ VAL(40)                                            SDWL  230
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYSDWL  240
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBSDWL  250
     2BAR                                                                SDWL  260
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACSDWL  270
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5SDWL  280
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),ASDWL  290
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,SDWL  300
     45,7),AS0(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX          SDWL  310
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6SDWL  320
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(SDWL  330
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     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)  SDWL  340
      DIMENSION GAP(2,11), DSW(2,11)                                     SDWL  350
      DIMENSION FZHOLD(2), FZHDRP(2)                                     SDWL  360
      DATA ENU/1.28E-5/                                                  SDWL  370
C                                                                        SDWL  380
      PBAR = PB-PINF                                                     SDWL  390
      PBHEAD = PBAR/(RHO*G)                                              SDWL  400
C                                                                        SDWL  410
CC    GAP OR WETTED DRAFT CALCULATION                                    SDWL  420
CC                                                                       SDWL  430
C                                                                        SDWL  440
      DO 5 J=1,2                                                         SDWL  450
      N = NSTA(J)                                                        SDWL  460
C                                                                        SDWL  470
      DO 5 K=1,N                                                         SDWL  480
      DD = ZS+Z+YY(J,K)*PHI-XX(1,K)*THETA+ETA(J,K)                       SDWL  490
      DDIN = DD-WATSLP*(XPWVXS-XX(J,K))                                  SDWL  500
      IF (DDIN.LT.BUBHGT) GO TO 1                                        SDWL  510
      IF (VAL(1)-TOLD.LT.DELPNT) GO TO 1                                 SDWL  520
      TOLD = VAL(1)                                                      SDWL  530
      WRITE (6,14) XX(J,K),VAL(1),DD                                     SDWL  540
    1 CONTINUE                                                           SDWL  550
      DSW(J,K) = (SIGN(1.,DD)+1.)*DD/2.                                  SDWL  560
      IF (DDIN) 2,4,4                                                    SDWL  570
    2 IF (DSW(J,K)-PBHEAD) 3,4,4                                         SDWL  580
    3 GAP(J,K) = -DDIN*(1.-(DSW(J,K))/PBHEAD)                            SDWL  590
      GO TO 5                                                            SDWL  600
    4 GAP(J,K) = 0.0                                                     SDWL  610
    5 CONTINUE                                                           SDWL  620
C                                                                        SDWL  630
CC                                                                       SDWL  640
CC    LEAKAGE AREA                                                       SDWL  650
C                                                                        SDWL  660
      ALSW = 0.0                                                         SDWL  670
C                                                                        SDWL  680
      DO 6 J=1,2                                                         SDWL  690
      N = NSTA(J)-1                                                      SDWL  700
C                                                                        SDWL  710
      DO 6 I=1,N                                                         SDWL  720
      ALSW = ALSW+(GAP(J,I)+GAP(J,I+1))*DELX/2.                          SDWL  730
    6 CONTINUE                                                           SDWL  740
C                                                                        SDWL  750
CC                                                                       SDWL  760
CC    CROSS-FLOW DRAG ON SIDEWALLS                                       SDWL  770
C                                                                        SDWL  780
      FYD = 0.0                                                          SDWL  790
      FKD = 0.0                                                          SDWL  800
      FND = 0.0                                                          SDWL  810
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C                                                                       SDWL  820
      DO 7 I=1,2                                                        SDWL  830
      N = NSTA(I)-1                                                     SDWL  840
C                                                                       SDWL  850
      DO 7 J=1,N                                                        SDWL  860
      DSWAV(I,J) = (DSW(I,J)+DSW(I,J+1))/2.                             SDWL  870
      VREL = V+XAVG(J)*R-(ZS-DSWAV(I,J)/2.)*P                           SDWL  880
      DF(I,J) = -HRHO*CDSW*VREL*ABS(VREL)*DELX*DSWAV(I,J)               SDWL  890
      FYD = FYD+DF(I,J)                                                 SDWL  900
      FND = FND+DF(I,J)*XAVG(J)                                         SDWL  910
    7 FKD = FKD-(ZS-DSWAV(I,J)/2.)*DF(I,J)                              SDWL  920
C                                                                       SDWL  930
CC                                                                      SDWL  940
CC    SET UP STERN LIMIT OF FORCE DETERMINATION                         SDWL  950
C                                                                       SDWL  960
      XSS = -XS                                                         SDWL  970
      GO TO 8                                                           SDWL  980
      ENTRY SIDWLM                                                      SDWL  990
      XSS = XMI(IX)                                                     SDWL 1000
    8 IP = 1.+(THETA*RAD-STH)/DTH                                       SDWL 1010
      IP = MAXO(MINO(IP,NTH),1)                                         SDWL 1020
      IP1 = MINO(IP+1,NTH)                                              SDWL 1030
      DTHETA = (IP-1)*DTH+STH                                           SDWL 1040
      DIP = (THETA*RAD-DTHETA)/DTH                                      SDWL 1050
C                                                                       SDWL 1060
CC    CALC REYNOLDS NO. AND DRAG COEFF.                                 SDWL 1070
C                                                                       SDWL 1080
      REY = U*XLSW/ENU                                                  SDWL 1090
      CDT = .427/(ALOG10(REY)-.407)**2.64                               SDWL 1100
C                                                                       SDWL 1110
CC    SIDEWALL FORCES, P/S                                              SDWL 1120
CC                                                                      SDWL 1130
C                                                                       SDWL 1140
      DO 11 J=1,2                                                       SDWL 1150
      WAREA = 0.0                                                       SDWL 1160
      N = NSTA(J)-1                                                     SDWL 1170
      NI = (XSS+XS)*N/XLSW+1.5                                          SDWL 1180
C                                                                       SDWL 1190
      DO 9 I=NI,N                                                       SDWL 1200
      ZOR1 = 1.                                                         SDWL 1210
      IF (DSWAV(J,I).EQ.0.0) ZOR1=0.0                                   SDWL 1220
    9 WAREA = WAREA+DELX*(2.*DSWAV(J,I)+ZOR1*AVBMSW)                    SDWL 1230
C                                                                       SDWL 1240
      FXH(J) = -HRHO*CDT*WAREA*U*U                                      SDWL 1250
      PM1 = 2*J-3                                                       SDWL 1260
      YLSW = PM1*YSW                                                    SDWL 1270
      DS = Z+ZS+YLSW*PHI                                                SDWL 1280
      DSS = DS-XSS*THETA                                                SDWL 1290
```

```
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5                                                    SDWL1300
      DSS = DSS*ZOR1                                                                  SDWL1310
      IDSS = 1.5+(DSS-SBB)/DBB                                                        SDWL1320
      IDSS = MINO(NBB,IDSS)                                                           SDWL1330
      BS = BB(IDSS)                                                                   SDWL1340
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5                                                    SDWL1350
      DSS = DSS*ZOR1                                                                  SDWL1360
      DRBOW = DSS-(XX(J,N+1)-XSS)*THETA                                               SDWL1370
      IF (DRBOW.LT.0.0) DRBOW=0.0                                                     SDWL1380
      A33S = (RHO*PI*BS**2)*0.125                                                     SDWL1390
      A22S = (RHO*.4*PI*DSS**2)*0.5                                                   SDWL1400
      IF (THETA.LT.0.0) A22S=.4*RHO*PI*DRBOW*DRBOW*0.5                                SDWL1410
      DSR = DS-(XREF-XS)*THETA                                                        SDWL1420
      ID = 1.+(DSR*12.-SDS)/DDS                                                       SDWL1430
      ID = MAXO(MINO(ID,NDS),1)                                                       SDWL1440
      DDSR = (ID-1)*DDS+SDS                                                           SDWL1450
      ID1 = MINO(ID+1,NDS)                                                            SDWL1460
      DID = (DSR*12.-DDSR)/DDS                                                        SDWL1470
      BC0 = AC0(1,ID,IP)                                                              SDWL1480
      BC00 = AC00(1,ID,IP)                                                            SDWL1490
      BC2 = AC2(1,ID,IP)                                                              SDWL1500
      BC5 = AC5(1,ID,IP)                                                              SDWL1510
      BC6 = AC6(1,ID,IP)                                                              SDWL1520
      BC0 = BC0+DID*(AC0(1,ID1,IP)-BC0)+DIP*(AC0(1,ID,IP1)-BC0+DID*(AC0(             SDWL1530
     11,ID1,IP1)-AC0(1,ID,IP1)-AC0(1,ID1,IP)+BC0))                                   SDWL1540
      BC00 = BC00+DID*(AC00(1,ID1,IP)-BC00)+DIP*(AC00(1,ID,IP1)-BC00+DID             SDWL1550
     1*(AC00(1,ID1,IP1)-AC00(1,ID,IP1)-AC00(1,ID1,IP)+BC00))                         SDWL1560
      BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2(             SDWL1570
     11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))                                   SDWL1580
      BC5 = BC5+DID*(AC5(1,ID1,IP)-BC5)+DIP*(AC5(1,ID,IP1)-BC5+DID*(AC5(             SDWL1590
     11,ID1,IP1)-AC5(1,ID,IP1)-AC5(1,ID1,IP)+BC5))                                   SDWL1600
      BC6 = BC6+DID*(AC6(1,ID1,IP)-BC6)+DIP*(AC6(1,ID,IP1)-BC6+DID*(AC6(             SDWL1610
     11,ID1,IP1)-AC6(1,ID,IP1)-AC6(1,ID1,IP)+BC6))                                   SDWL1620
C                                                                                     SDWL1630
CC    SHIFT MOMENT CENTER FROM XREF TO C.G.                                           SDWL1640
C                                                                                     SDWL1650
      BC00 = BC00-(XS-XREF)*BC0                                                       SDWL1660
      BC6 = BC6-(XS-XREF)*BC5                                                         SDWL1670
C                                                                                     SDWL1680
CC    HYDROSTATIC AND HYDRODYNAMIC FORCES                                             SDWL1690
C                                                                                     SDWL1700
      FZH(J) = -G*BC0-U*U*A33S*THETA-U*A33S*W+Q*U*(-BC2+A33S*XSS)-U*A33S              SDWL1710
     1*P*YLSW                                                                         SDWL1720
      FMH(J) = -U*XSS*XSS*A33S*Q+G*BC00+U*(A33S*XSS+BC2)*(W+U*THETA+YLSW              SDWL1730
     1*P)                                                                             SDWL1740
      FYH(J) = -A22S*U*(V+XSS*R-ZS*P)                                                 SDWL1750
      FNH(J) = FYH(J)*XSS-U*((V-ZS*P)*BC5+R*BC6)                                      SDWL1760
C                                                                                     SDWL1770
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```
C       ADD VERTICAL FORCE DUE TO DEADRISE PROJECTION OF LATERAL FORCE     SDWL1780
C                                                                          SDWL1790
        CTNDR = 0.0                                                        SDWL1800
        IF (DSS.LE.0.0) GO TO 10                                           SDWL1810
        CTNDR = (BS-BB(1))/DSS                                             SDWL1820
        IF (THETA.LT.0.0) CTNDR=.39391                                     SDWL1830
   10 CONTINUE                                                             SDWL1840
        FZHOLD(J) = FZH(J)                                                 SDWL1850
        FZHDRP(J) = PM1*FYH(J)*CTNDR*PROMO1                                SDWL1860
        FZH(J) = FZH(J)+FZHDPP(J)                                          SDWL1870
        IF (IMT.EQ.2) GO TO 11                                             SDWL1880
C                                                                          SDWL1890
C       CALC OF FORCE ON VENTRAL FINS REMOVED                              SDWL1900
C                                                                          SDWL1910
   11 CONTINUE                                                             SDWL1920
C                                                                          SDWL1930
        IF (IMT.EQ.2) GO TO 12                                             SDWL1940
C                                                                          SDWL1950
C       TOTAL SIDEWALL FORCES AMD MOMENTS                                  SDWL1960
C                                                                          SDWL1970
        FX = FXH(1)+FXH(2)                                                 SDWL1980
        FY = FYH(1)+FYH(2)                                                 SDWL1990
        FZ = FZH(1)+FZH(2)                                                 SDWL2000
        FK = (FZH(2)-FZH(1))*YSW+FKD-FY*ZS                                 SDWL2010
        FY = FY+FYD                                                        SDWL2020
        FM = FMH(1)+FMH(2)+ZS*FX                                           SDWL2030
        FN = FND+FNH(1)+FNH(2)+(FXH(1)-FXH(2))*YSW                         SDWL2040
C                                                                          SDWL2050
C       DRAG FORCE ON FINS REMOVED                                         SDWL2060
C                                                                          SDWL2070
   12 CONTINUE                                                             SDWL2080
C                                                                          SDWL2090
C       ADD ROLL DAMPING DUE TO VERTICAL WAVE GENERATION                   SDWL2100
C                                                                          SDWL2110
        DSS = Z+ZS-XSS*THETA                                               SDWL2120
        ZOR1 = (SIGN(1.,DSS)+1.)/2.                                        SDWL2130
        DSS = DSS*ZOR1                                                     SDWL2140
        DS = Z+ZS                                                          SDWL2150
        DSR = DS-(XREF-XS)*THETA                                           SDWL2160
        ID = 1.+(DSR*12.-SDS)/DDS                                          SDWL2170
        ID = MAXO(MINO(ID,NDS),1)                                          SDWL2180
        DDSR = (ID-1)*DDS+SDS                                              SDWL2190
        ID1 = MINO(ID+1,NDS)                                               SDWL2200
        DID = (DSR*12.-DDSR)/DDS                                           SDWL2210
        BC2 = AC2(1,ID,IP)                                                 SDWL2220
        BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2( SDWL2230
       11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))                       SDWL2240
        FKCLD = FK                                                         SDWL2250
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      FK = FK-PROMO2*YSW*YSW*BC2*P/PI                                    SDWL2260
      FZH(1) = FZH(1)+PROMO2/2.*YSW*BC2*P/PI                             SDWL2270
      FZH(2) = FZH(2)-PROMO2/2.*YSW*BC2*P/PI                             SDWL2280
      IF (PROMO3.EQ.1.0) WRITE (6,15) VAL(1),FZHOLD(1),FZHOLD(2),FZHDRP(SDWL2290
     11),FZHDRP(2),FZH(1),FZH(2),FKOLD,FK                                SDWL2300
      IF (ISIDWL.NE.ON) RETURN                                           SDWL2310
C                                                                        SDWL2320
      DO 13 I=1,2                                                        SDWL2330
C                                                                        SDWL2340
      DO 13 J=1,11                                                       SDWL2350
      GAP(I,J) = 12.0*GAP(I,J)                                           SDWL2360
   13 DSW(I,J) = 12.0*DSW(I,J)                                           SDWL2370
C                                                                        SDWL2380
      WRITE (6,16) ((GAP(I,J),J=1,11),I=1,2),((DSW(I,J),J=1,11),I=1,2),FSDWL2390
     1X,FY,FZ,FK,FM,FN                                                   SDWL2400
C                                                                        SDWL2410
C                                                                        SDWL2420
      RETURN                                                             SDWL2430
C                                                                        SDWL2440
   14 FORMAT (/10X,43HWATER CONTACT WITH TOP OF BUBBLE CHAMBER ATF7.2,14SDWL2450
     1H FT.    TIME =F7.2,19H SEC.    IMMERSION=F7.2,4H FT.)            SDWL2460
   15 FORMAT (/2X,'TIME=',1X,E15.4,2X,'OLD VERTICAL FORCES',2(5X,E15.4)/SDWL2470
     1 25X,'VERTICAL DEADRISE FORCES',2(5X,E15.4)/25X,'NEW VERTICAL FORCSDWL2480
     2ES',2(5X,E15.4)/25X,'OLD AND NEW ROLL MOMENTS',2(5X,E15.4)/)       SDWL2490
   16 FORMAT (/10X,8HSIDEWALL/25H GAP (FT.) (STERN TO BOW)/14H PORT SIDESDWL2500
     1WALL/11F10.5/14H STBD SIDEWALL/11F10.5/37H IMMERSION DEPTH (FT.) (SDWL2510
     2STERN TO BOW)/14H PORT SIDEWALL/11F10.5/14H STBD SIDEWALL/11F10.5/SDWL2520
     310X,26HSIDEWALL FX,FY,FZ,FK,FM,FN/6F15.4)                          SDWL2530
      END                                                                SDWL2540

      FUNCTION SHXYAX (X,Z,ANGYAX,PI)                                    SHX    10
C                                                                        SHX    20
      H = SQRT(X*X+Z*Z)                                                  SHX    30
      IF (X.EQ.0.0) GO TO 1                                              SHX    40
      ARG = Z/X                                                          SHX    50
      ANGOLD = ATAN(ARG)                                                 SHX    60
      IF (ANGOLD.GE.0.0) GO TO 2                                         SHX    70
      ANGNEW = ANGOLD+PI-ANGYAX                                          SHX    80
      GO TO 3                                                            SHX    90
    1 ANGNEW = PI*.50-ANGYAX                                             SHX   100
      GO TO 3                                                            SHX   110
    2 ANGNEW = ANGOLD-ANGYAX                                             SHX   120
    3 SHXYAX = H*COS(ANGNEW)                                             SHX   130
C                                                                        SHX   140
      RETURN                                                             SHX   150
      END                                                                SHX   160

      SUBROUTINE STNSL                                                   SSL    10
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C                                                                               SSL   20
      INTEGER ON                                                                SSL   30
      COMMON /AIR/ PINF,RHOINF,GAM                                              SSL   40
      COMMON /CONST/ PI,RAD,UO                                                  SSL   50
      COMMON /FORSS/ FX,FY,FZ,FK,FM,FN,QL,FMS                                   SSL   60
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,SSL   70
     110),XCP,ZCP                                                               SSL   80
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)SSL   90
     1,ARM2S(10)                                                                SSL  100
      COMMON /KSWTCH/ ITHRST                                                    SSL  110
      COMMON /LEAKER/ ALEAK,CFSS                                                SSL  120
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMSSL  130
     1I(20),XI(20),YI(20),ZI(20),XS,ZS,HRHO                                     SSL  140
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,ISSL  150
     1RUD,IPROP,IAEROD,IRHS                                                     SSL  160
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  SSL  170
      COMMON /SLCPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                            SSL  180
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVSSL  190
     1GS(10)                                                                    SSL  200
      COMMON /STSLR/ CPHI,CPHID                                                 SSL  210
      COMMON /VALOLD/ YOLD(20)                                                  SSL  220
      COMMON /VARBLE/ VAL(40)                                                   SSL  230
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYSSL  240
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBSSL  250
     2BAR                                                                       SSL  260
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VASSL  270
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VASSL  280
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)SSL  290
     3, (VAL(24),PB)                                                            SSL  300
      DIMENSION GAP(11), ELSKI(11), ELSKIL(11), AIRLEN(11), CTNSL(6,24) SSL  310
      DATA ENU,GPS,HINGHT/1.28E-5,.4644,1.875/                                  SSL  320
      DATA CTNSL/0.0,3.8,7.0,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.SSL  330
     10,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12SSL  340
     2.4,15.4,18.3,0.0,5.5,9.4,13.1,16.1,19.2,0.0,5.8,9.9,13.8,17.1,20.6SSL  350
     3,0.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,1SSL  360
     41.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,2SSL  370
     54.1,28.3,0.0,8.2,15.3,22.1,26.3,30.8,0.0,9.6,17.5,24.2,29.7,34.6,0SSL  380
     6.0,11.9,20.0,25.4,32.3,38.0,0.0,14.0,23.3,30.0,35.8,41.0,0.0,17.5,SSL  390
     725.5,32.5,39.7,44.5,0.0,21.6,30.0,38.7,42.0,47.0,0.0,24.6,33.7,41.SSL  400
     80,45.0,48.7,0.0,28.3,38.5,45.0,48.7,48.7,0.0,35.0,45.0,48.7,48.7,4SSL  410
     98.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,SSL  420
     $48.7,48.7,48.7,48.7,48.7/                                                 SSL  430
C                                                                               SSL  440
      IF (ELMAXS.GT.HINGHT) ELMAXS=HINGHT                                       SSL  450
C                                                                               SSL  460
      DO 1 J=1,11                                                               SSL  470
      GAP(J) = 0.0                                                              SSL  480
      ELSKI(J) = 0.0                                                            SSL  490
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```
      ELSKIL(J) = 0.0                                                    SSL  500
      AIRLEN(J) = 0.0                                                    SSL  510
    1 CONTINUE                                                           SSL  520
C                                                                        SSL  530
CC                                                                       SSL  540
CC    'EFDEP' IS THE EFFECTIVE LIFTING DEPTH OF THE STERN SEAL           SSL  550
C                                                                        SSL  560
      EFDEP = 6.0                                                        SSL  570
      MM = EFDEP                                                         SSL  580
      ALSS = 0.0                                                         SSL  590
      FX = 0.0                                                           SSL  600
      FZ = 0.0                                                           SSL  610
      FK = 0.0                                                           SSL  620
      FM = 0.0                                                           SSL  630
      FN = 0.0                                                           SSL  640
      AGAP1 = 0.0                                                        SSL  650
      AGAP2 = 0.0                                                        SSL  660
      AGAPA1 = 0.0                                                       SSL  670
      DELP = PSS-PB                                                      SSL  680
      IF (DELP.LT.0.0) DELP=0.0                                          SSL  690
      PBAR = PB-PINF                                                     SSL  700
C                                                                        SSL  710
CC    CALCULATE ELSKI HERE.                                              SSL  720
C                                                                        SSL  730
      SINDIF = SINTH-COSTH*THETA                                         SSL  740
      COSDIF = COSTH+SINTH*THETA                                         SSL  750
      X1 = XSS+ZSS*THETA-XLF*SINDIF                                      SSL  760
      Z1 = (-Z-ZSS+XSS*THETA-ELMAXS*COS(THETA))                          SSL  770
C                                                                        SSL  780
CC    CALCULATE GAP HERE.                                                SSL  790
C                                                                        SSL  800
      N = NSTA(4)                                                        SSL  810
C                                                                        SSL  820
      DO 2 K=1,N                                                         SSL  830
      ELSKI(K) = (ETA(4,K)-DETADX(K)*(XX(4,K)-X1)-Z1)+YY(4,K)*PHI-XPWV*WSSL  840
     1ATSLP                                                              SSL  850
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT                            SSL  860
      ELSKIL(K) = ELSKI(K)+GPS                                           SSL  870
      IF (ELSKIL(K).GT.HINGHT) ELSKIL(K)=HINGHT                          SSL  880
      IF (ELSKIL(K).LT.(HINGHT-ELMAXS)) ELSKIL(K)=HINGHT-ELMAXS          SSL  890
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXS)                                 SSL  900
      IF (GAP(K).LT.0.0) GAP(K)=0.0                                      SSL  910
      MM1 = ELSKIL(K)*12.0                                               SSL  920
      MM2 = MM1+1                                                        SSL  930
      MM3 = MM2+1                                                        SSL  940
      DLINC = ELSKIL(K)*12.0-MM1                                         SSL  950
      STNSL1 = CTNSL(MM,MM2)                                             SSL  960
      STNSL2 = CTNSL(MM,MM3)                                             SSL  970
```

```
      AIRLEN(K) = ((STNSL2-STNSL1)*DLINC+STNSL1)/12.0                    SSL  980
    2 CONTINUE                                                          SSL  990
C                                                                       SSL 1000
      N = NSTA(4)-1                                                     SSL 1010
C                                                                       SSL 1020
      DO 5 J=1,N                                                        SSL 1030
      ELSKIA = (ELSKI(J+1)+ELSKI(J))*0.5                                SSL 1040
      ELSKLA = (ELSKIL(J+1)+ELSKIL(J))*0.5                              SSL 1050
      AIRLAV = (AIRLEN(J+1)+AIRLEN(J))*0.5                              SSL 1060
      AGAP = ELSKLA-ELSKIA                                              SSL 1070
      AGAP1 = AGAP                                                      SSL 1080
      IF (AGAP.LT.GPS) AGAP=GPS                                         SSL 1090
      IF (AGAP1.GT.GPS) AGAP1=GPS                                       SSL 1100
      ARM1S(J) = XX(4,J)+ELSKIA*0.5                                     SSL 1110
      ARM2S(J) = ZS-ELSKIA                                              SSL 1120
      DFSS(J) = -DELP*DELYSS*AIRLAV/(GPS/AGAP)**2                       SSL 1130
      IF (AIRLAV.LE.0.0) GO TO 3                                        SSL 1140
      ARG = .5*RHO*U*U*AIRLAV*DELYSS                                    SSL 1150
      RESKI = U*AIRLAV/ENU                                              SSL 1160
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64                          SSL 1170
      TSKIS(J) = -ARG*CDTSKI                                            SSL 1180
C                                                                       SSL 1190
CC    THE FOLLOWING CARD REMOVES WATER DRAG EFFECTS OF STERN SEAL       SSL 1200
C                                                                       SSL 1210
      TSKIS(J) = 0.0                                                    SSL 1220
      GO TO 4                                                           SSL 1230
    3 TSKIS(J) = 0.0                                                    SSL 1240
    4 CONTINUE                                                          SSL 1250
      FX = FX+TSKIS(J)                                                  SSL 1260
      FZ = FZ+DFSS(J)                                                   SSL 1270
      FK = FK+DFSS(J)*YAVGS(J)                                          SSL 1280
      FM = FM-DFSS(J)*ARM1S(J)+TSKIS(J)*ARM2S(J)                        SSL 1290
      FN = FN-TSKIS(J)*YAVGS(J)                                         SSL 1300
      ALSS = ALSS+(GAP(J)+GAP(J+1))*DELYSS*0.5                          SSL 1310
      AGAP2 = AGAP2+AGAP1                                               SSL 1320
      AGAPA1 = AGAP2/J                                                  SSL 1330
    5 CONTINUE                                                          SSL 1340
C                                                                       SSL 1350
      ALSS = ALSS+ALEAK*(AGAPA1/GPS)                                    SSL 1360
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                 SSL 1370
      QL = CFSS*ALSS*SQFAC*SIGN(1.,PBAR)                                SSL 1380
      IF (ISTNSL.NE.ON) RETURN                                          SSL 1390
      WRITE (6,6) GAP,AIRLEN,FX,FY,FZ,FK,FM,FN                          SSL 1400
C                                                                       SSL 1410
C                                                                       SSL 1420
      RETURN                                                            SSL 1430
C                                                                       SSL 1440
    6 FORMAT (//12H  STERN SEAL/26H  GAP (FT.) PORT TO STBD. /11E11.3/28SSL 1450
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     1H  AIRLEN(FT.) PORT TO STBD. /11E11.3/10X,23HSTNSL FX,FY,FZ,FK,FM,SSL 1460
     2FN/6E15.4)                                                        SSL 1470
      END                                                               SSL 1480

      FUNCTION T1 (X)                                                   T1    10
C                                                                       T1    20
      IF (ABS(X)-.1) 1,1,2                                              T1    30
    1 T1 = X*(1.-X*X/10.0)/3.                                           T1    40
      RETURN                                                            T1    50
    2 T1 = (SIN(X)-X*COS(X))/(X*X)                                      T1    60
      RETURN                                                            T1    70
      END                                                               T1    80

      FUNCTION T2 (X)                                                   T2    10
C                                                                       T2    20
      IF (ABS(X)-.1) 1,1,2                                              T2    30
    1 T2 = 1.-X*X/6.                                                    T2    40
      RETURN                                                            T2    50
    2 T2 = SIN(X)/X                                                     T2    60
      RETURN                                                            T2    70
      END                                                               T2    80

      INTEGER CN                                                        WAVS  10
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY WAVS  20
      COMMON /CONST/ PI,RAD,UO                                          WAVS  30
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,WAVS  40
     110),XCP,ZCP                                                       WAVS  50
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)WAVS  60
     1,TSKIB(10)                                                        WAVS  70
      COMMON /GEOMSS/ DFTADX(11),DFTADT(11),ARM1S(10),DFSS(10),TSKIS(10)WAVS  80
     1,ARM2S(10)                                                        WAVS  90
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMWAVS 100
     1I(20),XI(20),YI(20),ZI(20),XS,ZS,HPHO                             WAVS 110
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)          WAVS 120
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUPHGT,DVWDOT                       WAVS 130
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IWAVS 140
     1RUD,IPROP,IAEROD,IRHS                                             WAVS 150
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  WAVS 160
      COMMON /RISER/ AMPTC                                              WAVS 170
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWAVS 180
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC         WAVS 190
      COMMON /VARBLE/ VAL(40)                                           WAVS 200
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYWAVS 210
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBWAVS 220
     2BAR                                                               WAVS 230
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACWAVS 240
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5WAVS 250
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),AWAVS 260
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     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,WAVS  270
     45,7),AS8(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX          WAVS  280
      DIMENSION WC0(2), WC00(2), WC1(2), WC2(2), WC3(2), WC4(2), WC5(2),WAVS  290
     1 WC6(2), WC7(2), WC8(2)                                           WAVS  300
      DIMENSION WS0(2), WS00(2), WS1(2), WS2(2), WS3(2), WS4(2), WS5(2),WAVS  310
     1 WS6(2), WS7(2), WS8(2)                                           WAVS  320
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6WAVS  330
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(WAVS  340
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB) WAVS  350
      EQUIVALENCE (VAL(16),ETACG)                                       WAVS  360
C                                                                       WAVS  370
      IF (NWAVE.EQ.0) RETURN                                            WAVS  380
C                                                                       WAVS  390
C     CALCULATION OF SHIFT OF XCPO                                      WAVS  400
C                                                                       WAVS  410
      XCPU = XCP+0.001975*(U*0.5921-30.0)**2-0.974                      WAVS  420
      XCPC = SHXYAX(XCPU,ZCP,THETA,PI)                                  WAVS  430
      GAMMA = BETA-PSI                                                  WAVS  440
      SIGAM = SIN(GAMMA)                                                WAVS  450
      COGAM = COS(GAMMA)                                                WAVS  460
      FO = -X*COSBET-Y*SINBET                                           WAVS  470
      DVOLW = 0.0                                                       WAVS  480
      ETACG = 0.0                                                       WAVS  490
      N = NSTA(3)                                                       WAVS  500
C                                                                       WAVS  510
      DO 1 J=1,N                                                        WAVS  520
      DETABX(J) = 0.0                                                   WAVS  530
    1 CONTINUE                                                          WAVS  540
C                                                                       WAVS  550
      N = NSTA(4)                                                       WAVS  560
C                                                                       WAVS  570
      DO 2 J=1,N                                                        WAVS  580
      DETADX(J) = 0.0                                                   WAVS  590
    2 CONTINUE                                                          WAVS  600
C                                                                       WAVS  610
C                                                                       WAVS  620
      DO 3 J=1,4                                                        WAVS  630
      N = NSTA(J)                                                       WAVS  640
C                                                                       WAVS  650
      DO 3 K=1,N                                                        WAVS  660
    3 ETA(J,K) = 0.0                                                    WAVS  670
C                                                                       WAVS  680
C                                                                       WAVS  690
      DO 4 J=1,2                                                        WAVS  700
      FXW(J) = 0.0                                                      WAVS  710
      FYW(J) = 0.0                                                      WAVS  720
      FZW(J) = 0.0                                                      WAVS  730
      FKW(J) = 0.0                                                      WAVS  740
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      FMW(J) = 0.0                                                      WAVS  750
      FNW(J) = 0.0                                                      WAVS  760
    4 CONTINUE                                                          WAVS  770
C                                                                       WAVS  780
      XSS = -XS                                                         WAVS  790
      IF (IMT.EQ.2) XSS = XMI(IX)                                       WAVS  800
      IP = 1+(THEBAR*RAD-STH)/DTH                                       WAVS  810
      IP = MAXO(MINO(IP,NTH),1)                                         WAVS  820
      IP1 = MINO(IP+1,NTH)                                              WAVS  830
      DTHETA = (IP-1)*DTH+STH                                           WAVS  840
      DIP = (THETA*RAD-DTHETA)/DTH                                      WAVS  850
C     TIME RISE FACTOR FOR WAVE AMPLITUDE                               WAVS  860
      AMPFAC = 1.-EXP(-TIME/AMPTC)                                      WAVS  870
C                                                                       WAVS  880
      DO 11 I=1,NWAVE                                                   WAVS  890
      OM1 = OMEGA(I)                                                    WAVS  900
      OM2 = OM1*OM1                                                     WAVS  910
      XWK = OM2/G                                                       WAVS  920
      AA = AW(I)*AMPFAC                                                 WAVS  930
      FT = OM1*TIME+XWK*FO                                              WAVS  940
      AL = XWK*COSAM                                                    WAVS  950
      IAA = 1+(ABS(AL)-SAL)/DAL                                         WAVS  960
      IAA = MAXO(MINO(IAA,NAL),1)                                       WAVS  970
      IAA1 = MINO(IAA+1,NAL)                                            WAVS  980
      DAA = (IAA-1)*DAL+SAL                                             WAVS  990
      DIA = (ABS(AL)-DAA)/DAL                                           WAVS 1000
      SALP = SIGN(1.,AL)                                                WAVS 1010
C                                                                       WAVS 1020
C     WAVE FORCES AND MOMENTS ON THE SIDEWALLS                          WAVS 1030
C                                                                       WAVS 1040
C                                                                       WAVS 1050
      DO 7 J=1,2                                                        WAVS 1060
      YLSW = (2*J-3)*YSW                                                WAVS 1070
      WE = FT+XWK*SIGAM*YLSW                                            WAVS 1080
      ST = SIN(WE)                                                      WAVS 1090
      CT = COS(WE)                                                      WAVS 1100
      DS = ZBAR+ZS+YLSW*PHIBAR                                          WAVS 1110
      DSR = DS-(XREF-XS)*THEBAR                                         WAVS 1120
      ID = 1.+(DSR*12.-SDS)/DDS                                         WAVS 1130
      ID = MAXO(MINO(ID,NDS),1)                                         WAVS 1140
      DDSR = (ID-1)*DDS+SDS                                             WAVS 1150
      DID = (DSR*12.-DDSR)/DDS                                          WAVS 1160
      ID1 = MINO(ID+1,NDS)                                              WAVS 1170
      DSS = DS-XSS*THEBAR                                               WAVS 1180
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5                                      WAVS 1190
      DSS = DSS*ZOR1                                                    WAVS 1200
      IDSS = 1.5+(DSS-SBB)/DBB                                          WAVS 1210
      IDSS = MINO(NBB,IDSS)                                             WAVS 1220
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      BS = BB(IDSS)                                                          WAVS1230
      CK = CCS(XWK*COGAM*XSS)                                                WAVS1240
      A33S = (RHO*PI*BS*BS)*0.125                                            WAVS1250
      SK = SIN(XWK*COGAM*XSS)                                                WAVS1260
      A22S = (RHO*.4*PI*DSS*DSS)*0.5                                         WAVS1270
      A42S = 0.0                                                             WAVS1280
C                                                                            WAVS1290
CC    INTERPOLATION OF WAVE TABLES                                           WAVS1300
C                                                                            WAVS1310
      K = 1                                                                  WAVS1320
      L = IAA                                                                WAVS1330
    5 CONTINUE                                                               WAVS1340
      BC0 = AC0(L,ID,IP)                                                     WAVS1350
      BC00 = AC00(L,ID,IP)                                                   WAVS1360
      BC1 = AC1(L,ID,IP)                                                     WAVS1370
      BC2 = AC2(L,ID,IP)                                                     WAVS1380
      BC3 = AC3(L,ID,IP)                                                     WAVS1390
      BC4 = AC4(L,ID,IP)                                                     WAVS1400
      BC5 = AC5(L,ID,IP)                                                     WAVS1410
      BC6 = AC6(L,ID,IP)                                                     WAVS1420
      BC7 = AC7(L,ID,IP)                                                     WAVS1430
      BC8 = AC8(L,ID,IP)                                                     WAVS1440
      BS0 = AS0(L,ID,IP)                                                     WAVS1450
      BS00 = AS00(L,ID,IP)                                                   WAVS1460
      BS1 = AS1(L,ID,IP)                                                     WAVS1470
      BS2 = AS2(L,ID,IP)                                                     WAVS1480
      BS3 = AS3(L,ID,IP)                                                     WAVS1490
      BS4 = AS4(L,ID,IP)                                                     WAVS1500
      BS5 = AS5(L,ID,IP)                                                     WAVS1510
      BS6 = AS6(L,ID,IP)                                                     WAVS1520
      BS7 = AS7(L,ID,IP)                                                     WAVS1530
      BS8 = AS8(L,ID,IP)                                                     WAVS1540
      WC0(K) = BC0+DID*(AC0(L,ID1,IP)-BC0)+DIP*(AC0(L,ID,IP1)-BC0+DID*(AWAVS1550
     1C0(L,ID1,IP1)-AC0(L,ID,IP1)-AC0(L,ID1,IP)+BC0))                        WAVS1560
      WC00(K) = BC00+DID*(AC00(L,ID1,IP)-BC00)+DIP*(AC00(L,ID,IP1)-BC00+WAVS1570
     1DID*(AC00(L,ID1,IP1)-AC00(L,ID,IP1)-AC00(L,ID1,IP)+BC00))              WAVS1580
      WC1(K) = BC1+DID*(AC1(L,ID1,IP)-BC1)+DIP*(AC1(L,ID,IP1)-BC1+DID*(AWAVS1590
     1C1(L,ID1,IP1)-AC1(L,ID,IP1)-AC1(L,ID1,IP)+BC1))                        WAVS1600
      WC2(K) = BC2+DID*(AC2(L,ID1,IP)-BC2)+DIP*(AC2(L,ID,IP1)-BC2+DID*(AWAVS1610
     1C2(L,ID1,IP1)-AC2(L,ID,IP1)-AC2(L,ID1,IP)+BC2))                        WAVS1620
      WC3(K) = BC3+DID*(AC3(L,ID1,IP)-BC3)+DIP*(AC3(L,ID,IP1)-BC3+DID*(AWAVS1630
     1C3(L,ID1,IP1)-AC3(L,ID,IP1)-AC3(L,ID1,IP)+BC3))                        WAVS1640
      WC4(K) = BC4+DID*(AC4(L,ID1,IP)-BC4)+DIP*(AC4(L,ID,IP1)-BC4+DID*(AWAVS1650
     1C4(L,ID1,IP1)-AC4(L,ID,IP1)-AC4(L,ID1,IP)+BC4))                        WAVS1660
      WC5(K) = BC5+DID*(AC5(L,ID1,IP)-BC5)+DIP*(AC5(L,ID,IP1)-BC5+DID*(AWAVS1670
     1C5(L,ID1,IP1)-AC5(L,ID,IP1)-AC5(L,ID1,IP)+BC5))                        WAVS1680
      WC6(K) = BC6+DID*(AC6(L,ID1,IP)-BC6)+DIP*(AC6(L,ID,IP1)-BC6+DID*(AWAVS1690
     1C6(L,ID1,IP1)-AC6(L,ID,IP1)-AC6(L,ID1,IP)+BC6))                        WAVS1700
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      WC7(K) = BC7+DID*(AC7(L,ID1,IP)-BC7)+DIP*(AC7(L,ID,IP1)-BC7+DID*(AWAVS1710
     1C7(L,ID1,IP1)-AC7(L,ID,IP1)-AC7(L,ID1,IP)+BC7))                    WAVS1720
      WC8(K) = BC8+DID*(AC8(L,ID1,IP)-BC8)+DIP*(AC8(L,ID,IP1)-BC8+DID*(AWAVS1730
     1C8(L,ID1,IP1)-AC8(L,ID,IP1)-AC8(L,ID1,IP)+BC8))                    WAVS1740
      WS0(K) = BS0+DID*(AS0(L,ID1,IP)-BS0)+DIP*(AS0(L,ID,IP1)-BS0+DID*(AWAVS1750
     1S0(L,ID1,IP1)-AS0(L,ID,IP1)-AS0(L,ID1,IP)+BS0))                    WAVS1760
      WS00(K) = BS00+DID*(AS00(L,ID1,IP)-BS00)+DIP*(AS00(L,ID,IP1)-BS00+WAVS1770
     1DID*(AS00(L,ID1,IP1)-AS00(L,ID,IP1)-AS00(L,ID1,IP)+BS00))          WAVS1780
      WS1(K) = BS1+DID*(AS1(L,ID1,IP)-BS1)+DIP*(AS1(L,ID,IP1)-BS1+DID*(AWAVS1790
     1S1(L,ID1,IP1)-AS1(L,ID,IP1)-AS1(L,ID1,IP)+BS1))                    WAVS1800
      WS2(K) = BS2+DID*(AS2(L,ID1,IP)-BS2)+DIP*(AS2(L,ID,IP1)-BS2+DID*(AWAVS1810
     1S2(L,ID1,IP1)-AS2(L,ID,IP1)-AS2(L,ID1,IP)+BS2))                    WAVS1820
      WS3(K) = BS3+DID*(AS3(L,ID1,IP)-BS3)+DIP*(AS3(L,ID,IP1)-BS3+DID*(AWAVS1830
     1S3(L,ID1,IP1)-AS3(L,ID,IP1)-AS3(L,ID1,IP)+BS3))                    WAVS1840
      WS4(K) = BS4+DID*(AS4(L,ID1,IP)-BS4)+DIP*(AS4(L,ID,IP1)-BS4+DID*(AWAVS1850
     1S4(L,ID1,IP1)-AS4(L,ID,IP1)-AS4(L,ID1,IP)+BS4))                    WAVS1860
      WS5(K) = BS5+DID*(AS5(L,ID1,IP)-BS5)+DIP*(AS5(L,ID,IP1)-BS5+DID*(AWAVS1870
     1S5(L,ID1,IP1)-AS5(L,ID,IP1)-AS5(L,ID1,IP)+BS5))                    WAVS1880
      WS6(K) = BS6+DID*(AS6(L,ID1,IP)-BS6)+DIP*(AS6(L,ID,IP1)-BS6+DID*(AWAVS1890
     1S6(L,ID1,IP1)-AS6(L,ID,IP1)-AS6(L,ID1,IP)+BS6))                    WAVS1900
      WS7(K) = BS7+DID*(AS7(L,ID1,IP)-BS7)+DIP*(AS7(L,ID,IP1)-BS7+DID*(AWAVS1910
     1S7(L,ID1,IP1)-AS7(L,ID,IP1)-AS7(L,ID1,IP)+BS7))                    WAVS1920
      WS8(K) = BS8+DID*(AS8(L,ID1,IP)-BS8)+DIP*(AS8(L,ID,IP1)-BS8+DID*(AWAVS1930
     1S8(L,ID1,IP1)-AS8(L,ID,IP1)-AS8(L,ID1,IP)+BS8))                    WAVS1940
      IF (K.EQ.2) GO TO 6                                                WAVS1950
      K = 2                                                              WAVS1960
      L = IAA1                                                           WAVS1970
      GO TO 5                                                            WAVS1980
    6 BC0 = WC0(1)+DIA*(WC0(2)-WC0(1))                                   WAVS1990
      BC00 = WC00(1)+DIA*(WC00(2)-WC00(1))                               WAVS2000
      BC1 = WC1(1)+DIA*(WC1(2)-WC1(1))                                   WAVS2010
      BC2 = WC2(1)+DIA*(WC2(2)-WC2(1))                                   WAVS2020
      BC3 = WC3(1)+DIA*(WC3(2)-WC3(1))                                   WAVS2030
      BC4 = WC4(1)+DIA*(WC4(2)-WC4(1))                                   WAVS2040
      BC5 = WC5(1)+DIA*(WC5(2)-WC5(1))                                   WAVS2050
      BC6 = WC6(1)+DIA*(WC6(2)-WC6(1))                                   WAVS2060
      BC7 = WC7(1)+DIA*(WC7(2)-WC7(1))                                   WAVS2070
      BC8 = WC8(1)+DIA*(WC8(2)-WC8(1))                                   WAVS2080
      BS0 = (WS0(1)+DIA*(WS0(2)-WS0(1)))*SALP                            WAVS2090
      BS00 = (WS00(1)+DIA*(WS00(2)-WS00(1)))*SALP                        WAVS2100
      BS1 = (WS1(1)+DIA*(WS1(2)-WS1(1)))*SALP                            WAVS2110
      BS2 = (WS2(1)+DIA*(WS2(2)-WS2(1)))*SALP                            WAVS2120
      BS3 = (WS3(1)+DIA*(WS3(2)-WS3(1)))*SALP                            WAVS2130
      BS4 = (WS4(1)+DIA*(WS4(2)-WS4(1)))*SALP                            WAVS2140
      BS5 = (WS5(1)+DIA*(WS5(2)-WS5(1)))*SALP                            WAVS2150
      BS6 = (WS6(1)+DIA*(WS6(2)-WS6(1)))*SALP                            WAVS2160
      BS7 = (WS7(1)+DIA*(WS7(2)-WS7(1)))*SALP                            WAVS2170
      BS8 = (WS8(1)+DIA*(WS8(2)-WS8(1)))*SALP                            WAVS2180
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C                                                                       WAVS2190
CC      SHIFT MOMENT CENTER FROM XREF TO C.G.                           WAVS2200
C                                                                       WAVS2210
        BCOO = BCOO-(XS-XREF)*BCO                                       WAVS2220
        BC3 = BC3-(XS-XREF)*BC1                                         WAVS2230
        BC4 = BC4-(XS-XREF)*BC2                                         WAVS2240
        BC6 = BC6-(XS-XREF)*BC5                                         WAVS2250
        BSOO = BSOO-(XS-XREF)*BSO                                       WAVS2260
        BS3 = BS3-(XS-XREF)*BS1                                         WAVS2270
        BS4 = BS4-(XS-XREF)*BS2                                         WAVS2280
        BS6 = BS6-(XS-XREF)*BS5                                         WAVS2290
C                                                                       WAVS2300
CC      CALCULATE WAVE FORCES AND MOMENTS                               WAVS2310
C                                                                       WAVS2320
        FZC = BS1-XWK*G*(BS2+BSO)-U*OM1*(-A33S*CK-AL*BS2)               WAVS2330
        FZS = BC1-XWK*G*(BC2+BCO)+U*OM1*(-A33S*SK+AL*BC2)               WAVS2340
        FMC = BS3-XWK*G*(BS4+BSOO)-U*OM1*(-A33S*XSS*CK-BC2-AL*BS4)      WAVS2350
        FMS = BC3-XWK*G*(BC4+BCOO)+U*OM1*(-A33S*XSS*SK-BS2+AL*BC4)      WAVS2360
        FYC = XWK*G*(BC5+BCO)-U*OM1*(-A22S*SK+AL*BC5)                   WAVS2370
        FYS = -XWK*G*(BS5+BSO)-U*OM1*(-A22S*CK-AL*BS5)                  WAVS2380
        FNC = XWK*G*(BC6+BCOO)-U*OM1*(-A22S*XSS*SK-BS5+AL*BC6)          WAVS2390
        FNS = -XWK*G*(BS6+BSOO)-U*OM1*(-A22S*XSS*CK-BC5-AL*BS6)         WAVS2400
        FKC = XWK*G*(BC7-BC8)+U*OM1*(-A42S*SK+AL*BC8)                   WAVS2410
        FKS = -XWK*G*(BS7-BS8)+U*OM1*(-A42S*CK-AL*BS8)                  WAVS2420
        FZW(J) = FZW(J)-AA*(FZC*CT+FZS*ST)                              WAVS2430
        FMW(J) = FMW(J)+AA*(FMC*CT+FMS*ST)                              WAVS2440
        FYW(J) = FYW(J)-AA*(FYC*CT+FYS*ST)*SIGAM                        WAVS2450
        FNW(J) = FNW(J)-AA*(FNC*CT+FNS*ST)*SIGAM                        WAVS2460
        FKW(J) = FKW(J)-AA*(FKC*CT+FKS*ST)*SIGAM                        WAVS2470
        FXW(J) = FXW(J)-2.*AA*RHO*G*BS*DSS*SK*CT                        WAVS2480
      7 CONTINUE                                                        WAVS2490
C                                                                       WAVS2500
        IF (IMT.EQ.2) GO TO 11                                          WAVS2510
C                                                                       WAVS2520
CC      WAVE ELEVATION AROUND THE SIDEWALLS AND SEALS                   WAVS2530
CC                                                                      WAVS2540
C                                                                       WAVS2550
        DO 8 J=1,4                                                      WAVS2560
        N = NSTA(J)                                                     WAVS2570
C                                                                       WAVS2580
        DO 8 K=1,N                                                      WAVS2590
        ETA(J,K) = ETA(J,K)+SIN(XWK*(-XX(J,K)*COGAM-YY(J,K)*SIGAM)+FT)*AA WAVS2600
      8 CONTINUE                                                        WAVS2610
C                                                                       WAVS2620
        ETACG = ETACG+AA*SIN(FT)                                        WAVS2630
        N = NSTA(3)                                                     WAVS2640
C                                                                       WAVS2650
        DO 9 J=1,N                                                      WAVS2660
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      ARG = AA*COS(XWK*(-XX(3,J)*COGAM)+FT)                                  WAVS2670
      DETABX(J) = DETABX(J)-XWK*COGAM*ARG                                    WAVS2680
    9 CONTINUE                                                               WAVS2690
C                                                                            WAVS2700
      N = NSTA(4)                                                            WAVS2710
C                                                                            WAVS2720
      DO 10 J=1,N                                                            WAVS2730
      ARG = AA*COS(XWK*(-XX(4,J)*COGAM)+FT)                                  WAVS2740
      DETADX(J) = DETADX(J)-XWK*COGAM*ARG                                    WAVS2750
   10 CONTINUE                                                               WAVS2760
C                                                                            WAVS2770
C                                                                            WAVS2780
C     WAVE PUMPING                                                           WAVS2790
C                                                                            WAVS2800
      X1 = XWK*XLBW*COGAM*0.5                                                WAVS2810
      X2 = XWK*XBBW*SIGAM*0.5                                                WAVS2820
      FTT = FT-XWK*XCPC*COGAM                                                WAVS2830
      DVOLW = DVOLW+AA*ABW*T2(X1)*T2(X2)*SIN(FTT)                            WAVS2840
   11 CONTINUE                                                               WAVS2850
C                                                                            WAVS2860
      IF (TIME.EQ.0.0) GO TO 12                                              WAVS2870
      DVWDOT = (DVOLW-DVOLWO)/(TIME-TIMEO)                                   WAVS2880
   12 DVOLWO = DVOLW                                                         WAVS2890
      TIMEO = TIME                                                           WAVS2900
      IF (IMT.EQ.2) RETURN                                                   WAVS2910
C                                                                            WAVS2920
C     TOTAL WAVE FORCES AND MOMENTS                                          WAVS2930
C                                                                            WAVS2940
      FXWAV = FXW(1)+FXW(2)                                                  WAVS2950
      FYWAV = FYW(1)+FYW(2)                                                  WAVS2960
      FZWAV = FZW(1)+FZW(2)                                                  WAVS2970
      FKWAV = FKW(1)+FKW(2)+(FZW(2)-FZW(1))*YSW+FYWAV*ZBAR                   WAVS2980
      FMWAV = FMW(1)+FMW(2)-FXWAV*ZBAR                                       WAVS2990
      FNWAV = FNW(1)+FNW(2)+(FXW(1)-FXW(2))*YSW                              WAVS3000
      IF (IWAVES.NE.ON) RETURN                                               WAVS3010
      WRITE (6,13) ((ETA(I,J),J=1,11),I=1,4),ETACG,DVOLW,FXWAV,FYWAV,FZWWAVS3020
     1AV,FKWAV,FMWAV,FNWAV                                                   WAVS3030
C                                                                            WAVS3040
C                                                                            WAVS3050
      RETURN                                                                 WAVS3060
C                                                                            WAVS3070
   13 FORMAT (/10X,5HWAVES/63H WAVE ELEVATIONS AT CRAFT STATIONS RELATIVWAVS3080
     1E TO CALM WATER (FT.)/14H PORT SIDEWALL/11F10.5/14H STBD SIDEWALL/WAVS3090
     211F10.5/9H BOW SEAL/11F10.5/11H STERN SEAL/11F10.5/25H WAVE ELEVATWAVS3100
     3ICN AT C.G. =F10.5,10X,43HPLENUM VOLUME LOST DUE TO WAVES (CU. FT.WAVS3110
     4) =F15.5/10X,23HWAVES FX,FY,FZ,FK,FM,FN/6E15.4)                       WAVS3120
      END                                                                    WAVS3130
```

LIST OF REFERENCES

1. Janes' Surface Skimmers Hovercraft and Hydrofoils, 9th ed., Franklin Watts, Inc., New York, 1975-1976.

2. Oceanics Incorporated, Report No. 71-84A, August 1971, Technical Industrial Park, Plainview, N. Y., 11803.

3. Leo, D. G., and Boncal, R., XR-3 Surface Effects Ships Test Craft: A Mathematical Model and Simulation Program with Verification, Master's Thesis, Naval Postgraduate School, December, 1973.

4. Layton, D. M., Evaluation of the XR-3 Test Craft, Annual Report, Naval Postgraduate School, 1971.

5. Finley, R. A., Refinements of the Seal Subroutines and Fan Air Flow Maps for the XR-3 Loads and Motion Program, Master's Thesis, Naval Postgraduate School, December 1974.

6. Forbes, G. T., Validation of the Nonlinear Six Degrees of Freedom Mathematical Model of the XR-3 Captured Air Bubble Surface Effect Ship in Calm Water, Master's Thesis, Naval Postgraduate School, December, 1974.

7. Menzel, R. F., Study of the Roll and Pitch Transients in Calm Water Using the Simulated Performance of XR-3 Surface Effect Ship Loads and Motion Computer Program, Master's Thesis, Naval Postgraduate School, December 1975.

8. Mitchell, W. R., Investigation of Methods to Optimize Captured Air Bubble Surface Effect Ship Digital Simulation for Irregular Sea Conditions, Master's Thesis, Naval Postgraduate School, September 1974.

9. Private communication from F. Wilson to Professor A. Gerba, dated, 10 May 1974

10. Private communication from J. E. Blaloch to Professor A. Gerba, dated, 9 September 1975

11. Principles of Naval Architecture, Revised ed., Society of Naval Architects and Marine Engineers, 1967.

12. W. R., Church Computer Center, Naval Postgraduate School, Users Manual, 1st. ed., March 1970.

13. IBM Systems Library, IBM System/360 Operating System FORTRAN IV (G and H) Programmers Guide, Form No. (25) GC-28-6817, 5th ed., September 1973.

14. Booth, B. F., Naval Postgraduate School Thesis. To be published in June 1976.

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